1951 SAE HANDBOOK

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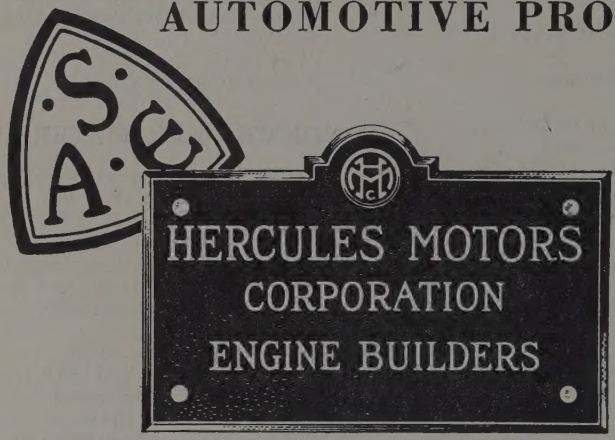
TEAMWORK...

IN THE INTERESTS OF AUTOMOTIVE PROGRESS!



HERCULES ENGINES 3 TO 500 H. P.

GAS AND GASOLINE ENGINES

Model	Bore and Stroke	Cu. In. Displ.
Two Cylinder		
BXB	2⅞" x 3"	39
NXA	3" x 4"	56.5
NXB	3¼" x 4"	66.3
Four Cylinder		
ZXA	2½" x 3"	59
ZXB	2⅝" x 3"	65
IXA	3" x 4"	113
IXB	3¼" x 4"	133
JX4E	3½" x 4¼"	164
JX4C	3¾" x 4¼"	188
JX4D	4" x 4¼"	214
Six Cylinder		
QXA	3⅛" x 4⅛"	190
QXB	3¼" x 4⅛"	205
QXC	3⅜" x 4⅛"	221
QXLD	3 7/16" x 4¼"	236.7
JXE	3½" x 4¼"	245
JXB	3⅝" x 4¼"	263
JXC	3¾" x 4¼"	282
JXD	4" x 4¼"	320
JXLD	4" x 4½"	339
WXC-3	4¼" x 4½"	383
WXLC	4" x 4¾"	358
WXLC-3	4¼" x 4¾"	404
TDXB	4⅜" x 5¼"	474
RXB	4½" x 5¼"	501
RXC	4⅝" x 5¼"	529
RXLC	4⅝" x 5¼"	529
RXLD	4¾" x 5¼"	558
RXLDH	4¾" x 5¼"	558
HXB	5" x 6"	707
HXC	5¼" x 6"	779
HXD	5½" x 6"	855
HXE	5¾" x 6"	935

DIESEL ENGINES

Model	Bore and Stroke Inches	Piston Displ. Cu. In.
Two Cylinder		
DIXC	4" x 4½"	113.1
DIXD	4¼" x 4½"	127.5
Four Cylinder		
DIX4B	3¼" x 4"	133
DIX4D	3⅝" x 4"	166
DOOB	3¾" x 4½"	198.8
DOOC	4" x 4½"	226.2
DOOD	4¼" x 4½"	255
Six Cylinder		
DIX6D	3⅝" x 4"	249
DJXB	3½" x 4½"	260
DJXC	3¾" x 4½"	298
DJXH	3¾" x 4½"	298
DJXHF	3¾" x 4½"	298
DWXC	4" x 4¾"	358
DWXD	4¼" x 4¾"	404
DWXLD	4¼" x 5"	426
DWXLDF	4¼" x 5"	426
DRXB	4⅜" x 5¼"	474
DRXC	4⅝" x 5¼"	529
DFXB	5" x 6"	707
DFXC	5¼" x 6"	779
DFXD	5½" x 6"	855
DFXE	5⅝" x 6"	895
DFXH	5¾" x 6"	935
DFXHF	5¾" x 6"	935
Eight Cylinder		
DNX V-8B	5¾" x 6"	1247
DNX V-8C	6" x 6"	1348
DNX V-8D	6¼" x 6"	1468
DNX V-8DS	6¼" x 6"	1468

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HERCULES ENGINES

HERCULES MOTORS CORPORATION CANTON, OHIO, U.S.A.

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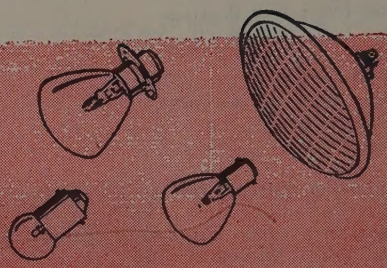
YOUR BEST BET FOR AUTO BULB BUSINESS



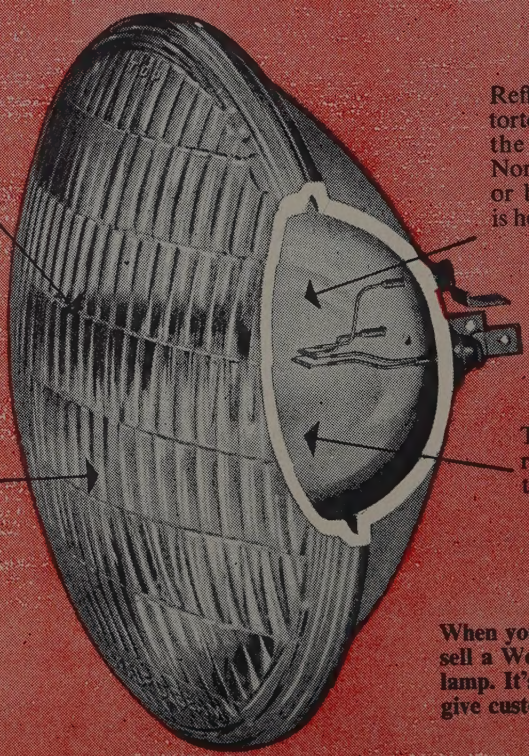
In your business you're selling safety. That's why you carry wiper blades, fan belts, cables, and light bulbs. That's why you check for worn tires, bad brakes, loose connections, and burned-out lamps.

Isn't it logical, then, that you should handle the lamps that can be depended upon to give maximum See-ability on the road? Lamps that are the best that money can buy. Westinghouse lamps!

A WESTINGHOUSE SEALED BEAM LAMP IS A PRECISE OPTICAL SYSTEM.

The lens has 121 little prisms to direct every bit of the light to the right spot.

Reflector can't be distorted by pressure from the holding clamps. Nor will it ever tarnish or blacken, because it is hermetically sealed.



The whole unit is all glass and heat toughened during manufacture so that it resists shocks, flying stones, and jars and jolts.

The filaments are accurately positioned and they stay in line.

When you're selling a headlight lamp, sell a Westinghouse Sealed Beam lamp. It's the lamp you know will give customer satisfaction.

YOU CAN BE SURE...IF IT'S Westinghouse

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SAE Standardization Publications

SAE Handbook contains three classes of reports:

1. SAE Standards, which are specifications based on sound, established engineering practice.
2. SAE Recommended Practices, which are recommendations based on sound engineering principles and are intended as guides toward standard engineering practice.
3. SAE General Information reports, which present data useful to SAE Handbook users.

SAE Handbook Reprints available include "SAE Recommended Practice on Hydrodynamic-Drive Terminology," "Iron and Steel Standards and Specifications," "Lighting Equipment and Photometric Tests," "SAE Standards and Recommended Practices referenced in proposed revisions of the Motor Carrier Safety Regulations currently under consideration by the Interstate Commerce Commission," and "SAE Standard on Commerical-Vehicle Nomenclature."

SAE Automotive Drafting Standards are printed on sheets for insertion in a standard three-ring binder. Part I includes sections on Drawing Forms, Lines and Line Work, Lettering, Sectioning, Projection, Dimensioning, Decimal Dimensioning, Limits and Tolerances, Screw Threads, Drawing Revisions, Layout Forms, Layout Practice, and Checking Practice. Part II includes sections on Castings, Die Castings, Springs, Powder Metallurgy, Surface Finish, Chassis Frames, Abbreviations and Symbols, and Definitions and Notes. SAE Automotive Drafting Standards are sold as a unit, with or without three-ring binder. Also, bound copies of Part I are sold separately.

SAE Aeronautical Drafting Manual covers the drafting practices of the aircraft-engine, aircraft-propeller, and aircraft-accessory manufacturers and airline operators. The manual contains loose-leaf sections on Preparation of Drawings, Dimensioning by the Decimal System, Notes, Abbreviations and Symbols, Definitions, Threads, Gears, Splines and Serrations, Forgings, Finish Marks and Special Finishes, and Springs—plus tables of data useful to draftsmen, designers, and other engineers.

SAE aeronautical standardization publications cover design, dimensional, and parts standards for aircraft engines, propellers, accessories, and their components and installations as well as materials and process specifications for all phases of the aeronautical industry. The publications are issued in looseleaf-sheet form and sold individually as well as in sets of AMS's, AS's and ARP's, and AIR's. Numerical indexes of AMS's and of AS's, ARP's, and AIR's are available from the Society.

Aeronautical Material Specifications (AMS) are material and process specifications conforming to sound, established engineering and metallurgical practices in the aircraft industry. AMS's are given numbers prefixed by "AMS."

Aeronautical Standards (AS) are (1) design standards conforming with sound, established engineering practices in the aircraft industry; (2) parts standards conforming with engineering practices in the engine, propeller, accessory-equipment and airline industries; or (3) other aeronautical specifications that do not fall within the category of AMS's. AS's are given numbers prefixed by "AS."

Aeronautical Recommended Practices (ARP) are dimensional designs or performance recommendations based on sound engineering principles and are intended as guides toward standard engineering practice. ARP's are given numbers prefixed by "ARP."

Aeronautical Information Reports (AIR) contain engineering data of sufficient value to warrant publication but which do not lend themselves to the classification of standards or recommended practices. AIR's are given numbers prefixed by "AIR."

SAE Aircraft Engine Test Code is similar to the SAE Standard Engine Test Codes described in this book. The aircraft code forms include the instructions in pamphlet form with pages numbered AA-1–AA-9; Mechanical Information Sheets AB-1 and AB-2; Log Sheet AC; Temperature Corrections for Mercury Columns, Sheet AD-1; Vapor Pressure Chart, Sheet AD-2; Full Throttle Horsepower Correction Chart, Sheet AD-3; Horsepower Correction Factors for Carburetor Air Temperature, Sheet AD-4; and curve sheets AD-5–AD-7. The Society sells pamphlet and sheets separately as well as in sets.

All the foregoing publications are prepared by the Society. Address requests for prices and orders to

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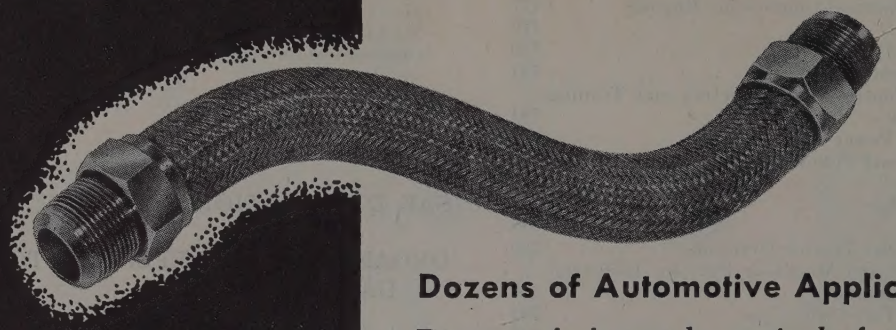
Titeflex All-Metal Flexible Tubing



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Dozens of Automotive Applications

Because it is made *entirely from metal,* Titeflex tubing possesses the inherent strength of metal. Yet it is entirely flexible to facilitate installation and to counteract vibration. It is manufactured from brass, bronze, stainless, monel and inconel, in a complete range of sizes, to fill most requirements of temperature, pressure and corrosion-resistance.

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Titeflex can supply complete ignition shielding systems or component parts for *all* reciprocating and gas turbine engines, in accordance with AN specifications. These are available to provide efficient shielding at temperatures from —70° to 450° F. and to conform to all existing water-proofing requirements.

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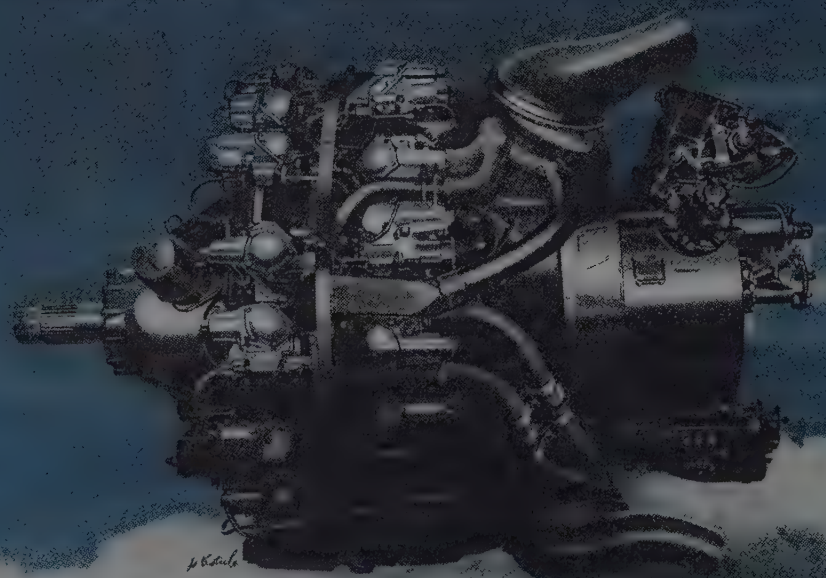

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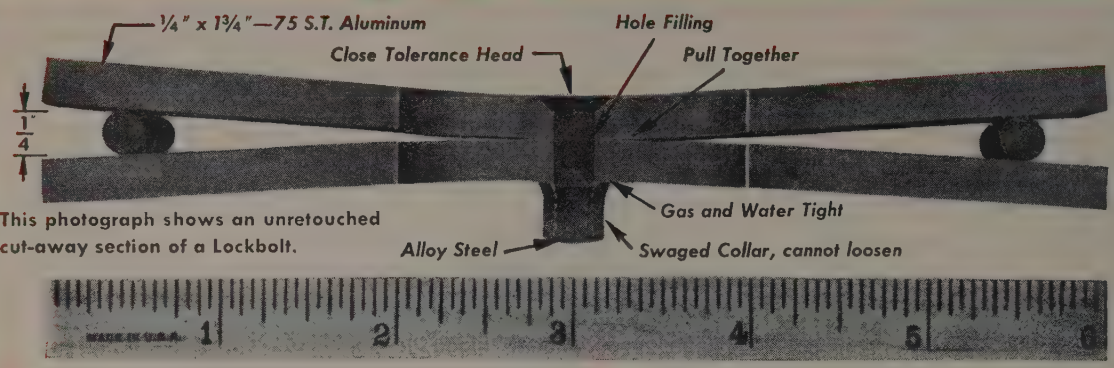
No Other Fasteners DO SO MUCH FOR AVIATION AS *Huck* LOCKBOLTS



● Huck Lockbolts speed up assembly rates—each two-man team can install 30 fasteners per minute.

● Huck Lockbolts provide optimum tightness without torque wrenching.

WRITE US *Today!*

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● Up to 35% Lighter in Weight

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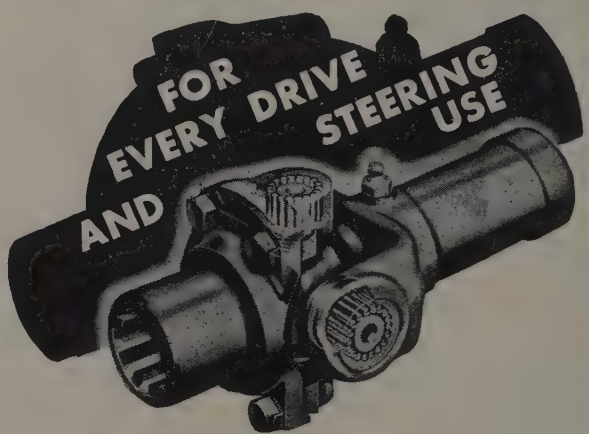

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HELI-COIL SCREW THREAD INSERTS ELIMINATE ALL SCREW THREAD TROUBLES

Designers and production men face special problems in threading all materials for assembly . . . problems concerned with the strength, durability and serviceability of threads.

Product failure frequently results from thread troubles such as wear, stripping, vibration, abrasion, corrosion, galling, seizure and electrolysis.

These problems are not peculiar to the light metals and plastics but occur in all metals, even iron and steel, and in die-castings and centrifugal castings.

All the problems of thread wear and thread failure can now be eliminated by the use of Heli-Coil Screw Thread Inserts—and we repeat: ELIMINATED!

WHAT ARE HELI-COIL INSERTS?

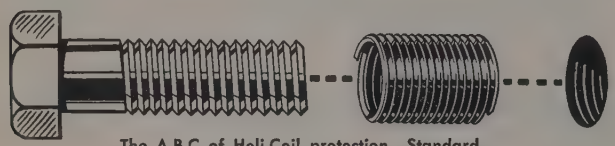
They are precision-formed coils of stainless steel wire which fit into the tapped hole between the male thread of the stud or bolt and the female thread of the mating member.

WHAT DO HELI-COIL INSERTS DO?

They meet all military, industrial and aircraft requirements for vibration, fatigue, tension and torsion loads. They save as much as 75% in weight of metal, and up to 50% in space compared with solid bushings. They permit better design with smaller bosses and flanges. They permit repeated assembly and disassembly without wear, and provide complete protection against thread wear, abrasion and corrosion.

WHAT ARE THEIR SPECIFICATIONS?

They are designed for National Coarse and Fine Threads, taper pipe threads, automotive and aviation spark plug threads. Made in all standard sizes and lengths and precision-formed for Class 3 fit. Heli-Coil Inserts and suitable taps and gages are also available for Class 2 and 2B.



The A-B-C of Heli-Coil protection. Standard bolt fits in Heli-Coil Insert inside oversize tap.

WHAT DO HELI-COIL INSERTS OFFER THE DESIGNER?

Simpler design . . . fewer bolts, shorter thread engagements, no costly solid bushings, lighter boss and flange design, no through-holes where blind holes are better.

Simpler assembly . . . no secondary machining.

Lower Cost . . . 75% less than solid bushings.

Less Space . . . 50% less than solid bushings.

Greater strength, even in short thread engagements.

Complete freedom from screw thread damage . . . outlasts the product.

HELI-COIL INSERTS AID PRODUCTION SALVAGE

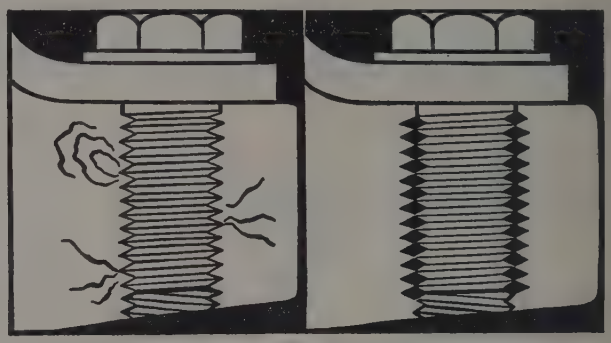
Castings or parts rejected because of production error or failure in drilling or tapping can now be quickly and economically salvaged with Heli-Coil Inserts. Easily installed, they are invisible to the eye and provide a stronger, better assembly and fit than the original design.

One prominent automotive manufacturer saved over $200,000 in 1950 by salvaging castings with Heli-Coil Screw Thread Inserts.

With material shortages and higher production costs, you cannot afford to scrap or remelt castings solely because of drilling or tapping error.

HELI-COIL INSERTS FACILITATE MAINTENANCE AND REPAIR

Weak, worn or damaged threads—rusted, "frozen" or wobbly bolts and cap screws are the cause of frequent maintenance and repair problems. Solve them economically, easily and on the spot with Heli-Coil Inserts—the retread for screw threads. These precision-formed inserts of stainless steel wire permanently repair and restore any and all threads. They add strength, permanent protection, and are forever free from galling, seizure or corrosion.



Drawing shows typical strains imparted to block through worn threads (left). Heli-Coil Inserts of stainless steel wire eliminate strains on mating member (right).

Eliminate further down-time of valuable equipment, speed up assembly and disassembly with Heli-Coil Inserts and get rid of your inventory of oversize nuts, bolts and studs.

HELI-COIL INSERTS ARE QUICKLY AND EASILY INSTALLED

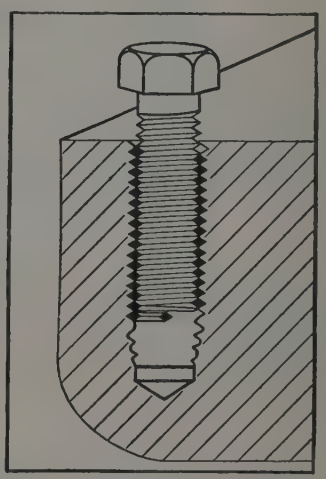
Whether by power tool or by hand the installation of Heli-Coil Inserts consists of only 3 simple steps which are easily and quickly done by any mechanic.

(1) Drill with appropriate drill of proper size.

(2) Tap with genuine Heli-Coil tap of recommended size.

(3) Install Heli-Coil Insert with simple Heli-Coil hand tool or power tool.

Send for Heli-Coil bulletin 650 showing complete Design Data and bulletin 349 on Salvage and Service. Typical drawings are shown for guidance in specifying Heli-Coil Inserts . . . specifications given for blind-hole & through-hole installation. Tabulations show Heli-Coil Inserts, tools & gages to be used for National Coarse & Fine Thread series, automotive & aviation spark plug threads.



Cross-section of blind hole with thread protected by Heli-Coil Insert.

HELI-COIL *Protecting Screw Threads for Industry*

Heli-Coil is a registered U.S. Tradename

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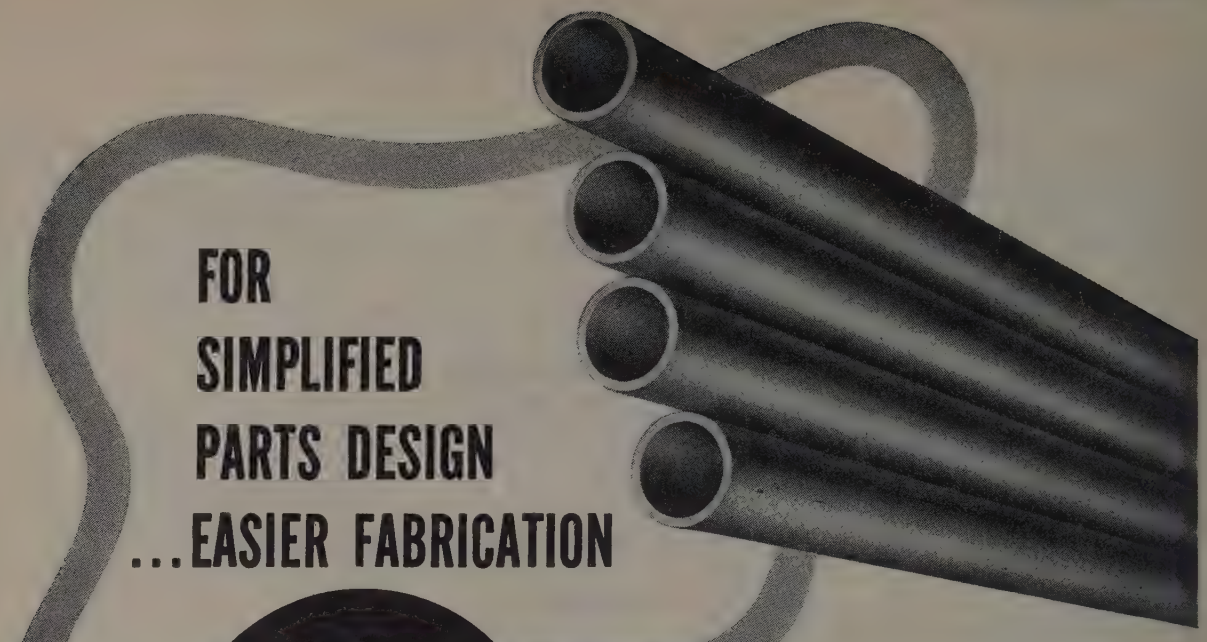

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Seamless tubes—hot-finished, cold-drawn, or rocked
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SHAPES
Round, square, rectangular, or special shapes

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Stainless steels—B&W Croloys 12 to 27
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Carbon steels—in various grades

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Up to 9 5/8 inches outside diameter in a wide range of wall thicknesses

SURFACE FINISHES
As rolled, as drawn, as welded, flash removed, turned, scale-free, and polished

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Made to any of the standard specifications such as those of the ASTM and U. S. Government

QUALITY
Open-hearth and electric-furnace steels, including aircraft and magnaflux qualities

CONDITION
Unannealed, annealed, tempered, normalized, or otherwise heat-treated as required

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Upsetting, swaging, expanding, bending, safe-ending, and machining

You can improve and simplify product design—make many forming, machining, and welding operations easier — with B&W Tubing, because it provides the properties you need in your finished product—but in the combination you need for easy fabrication.

B&W tubing is made in stainless, alloy, and carbon steels, seamless and welded, hot-finished, cold-drawn, or rocked, in a wide range of sizes, and in various surface finishes and heat-treated conditions, so that you can select the most economical tubing for your specific manufacturing procedure and end-use.

And you can be sure of getting the properties and characteristics you want in every foot of B&W Tubing, because manufacturing methods at B&W keep tubing quality consistently uniform.

For help in finding the tubing best suited to your particular use, feel free to call on our technical staff. Their broad experience in tubing applications can be of value to you.

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(*Continued on next page.*)

PALNUT SELF-LOCKING NUTS

TRADE MARK

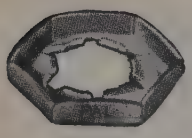
Widely used on Automobiles and Trucks to provide

QUICK, SECURE FASTENING AT LOW COST!

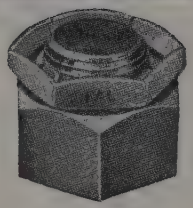
PALNUT Self-locking nuts are single thread nuts, made of spring tempered steel and accurately formed to fit standard screw threads. Unfailing double-locking action holds tight under vibration. High speed assembly with hand or power tools. Cost less than most other locking methods. For heavy assemblies, apply PALNUTS on top of ordinary nuts; for light assemblies, use PALNUTS alone.

Write for samples and literature.

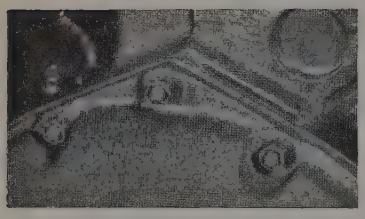
Regular Type PALNUTS



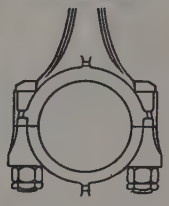
Used as Lock Nuts



Typical Applications



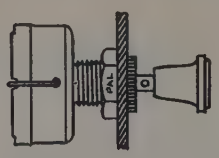
PALNUTS lock regular nuts holding transmission housing to engine



PALNUTS are standard on Connecting Rods of most automobiles and trucks.

Popular Automotive Sizes

Type of Palnut	Size	Width Across Flats	Height	Palnut Part No.
Regular	1/4" —28 N.F.	7/16"	.118"	14L28
Regular	5/16"—24 N.F.	1/2"	.126"	516L24
Regular	3/8" —24 N.F.	9/16"	.140"	38L24
Regular	7/16"—20 N.F.	5/8"	.150"	716L20
Regular	1/2" —20 N.F.	3/4"	.166"	12L20
Regular	5/16"—18 N.C.	9/16"	.138"	516R18
Regular	3/8" —16 N.C.	5/8"	.156"	38R16



PALNUT used alone as backing-up nut on automotive switches and controls.

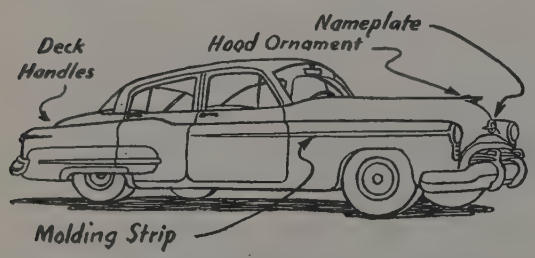
* Also used on main bearings, hand brakes, mounting of engines, radiators, shock absorbers, etc.

Other Types of PALNUTS

Washer Type

Acorn Type

Wing Type



Also used on medallions, glove compartments, tail and parking lights, instrument assemblies, grilles, etc.

Popular Automotive Sizes

Type of Palnut	Size	Width Across Flats	Washer Diameter	Height	Palnut Part No.
Washer	#10—32 m.s.	3/8"	17/32"	.166"	10M32E
Washer	#10—24 m.s.	3/8"	1/2"	.212"	10M24D1
Washer	#10—24 m.s.	3/8"	3/4"	.248"	10M24D2
Washer	#12—24 m.s.	3/8"	9/16"	.220"	12M24D-12
Washer	1/4"—20 N.C.	7/16"	19/32"	.239"	14R20D
Washer	1/4"—20 N.C.	7/16"	13/16"	.271"	14R20D1
Acorn	#8—32 m.s.	11/32"		.297"	8M32C
Acorn	#10—24 m.s.	3/8"		.328"	10M24C
Acorn	1/4"—20 N.C.	7/16"		.380"	14R20C
Wing	#10—24 m.s.	7/8"*		.375"	10J24
Wing	1/4"—20 N.C.	1"*		.400"	14J20

* Extremities—Wing to Wing

Send for Catalog #573, showing complete range of types and sizes of PALNUTS. Samples on request.

THE PALNUT COMPANY
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Detroit Office: 8100 Lyndon Ave.

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HIGHWAY TRAFFIC STANDARDS CORRELATING COMMITTEE, G. W Laurie (F. K. Glynn, *Alt.*)

* STANDARDIZATION AND UNIFICATION OF SCREW THREADS (B1)

Scope: Nomenclature of screw threads; form of threads; diameters and pitches or screws for various uses; classification of thread fits; tolerances and allowances for threaded parts; and the gaging of threads. Screw threads for fire hose couplings are not included within this scope.

Earle Buckingham, P. L. Houser, Gustaf Carvelli, H. A. Marchant

PIPE THREAD (B2)

Scope: The American (Briggs) Standard taper and straight pipe threads, plumber's threads, and threads for thin tubes, basic and limiting dimensions of the elements, formulas for calculating the dimensions, working tolerances, gages, and methods of gaging.

R. F. Holmes, H. A. Marchant

BALL AND ROLLER BEARINGS (B3)

Scope: Boundary dimensions of ball and roller bearings for radial and thrust loads or combinations thereof, as affecting the interchange or replacement of such bearings in machinery; and the tolerances on such dimensions.

H. N. Parsons, K. G. Roth

* STANDARDS FOR SMALL TOOLS AND MACHINE TOOL ELEMENTS (B5)

Scope: The standardization of the elements of machine tool construction and operation, and of tool and work holding elements and associated appurtenances, including driving mechanisms that constitute an inherent part of the machine tool; and relating primarily to the use of machine tools on manufacturing operations in mechanical industry; sizes, capacities, and clearances of machine tools and of other work and tool holding parts; length of stroke, travel, and other movements and adjustments; parts and elements for holding and adjusting, guiding or aligning work or tools, including bolts and nuts, and taper, split, straight, and dowel pins; slots, bushings, and tapers; drills, taps, reamers, cutters, countersinks, chucks, jigs, etc.

W. L. Barth, P. L. Houser, Earle Buckingham, T. M. Logan, R. A. Wilhelm

STANDARDIZATION OF GEARS (B6)

Scope: Standardization of spur, helical, herringbone, bevel, and worm gearing, covering general gear proportions; tooth form; mounting of gears; inspection of gears; nomenclature.

G. L. McCain, Paul Pritchard

STANDARDIZATION OF SHAFTING (B17)

Scope: Diameters of transmission and machinery shafting and tolerances on shafting stock; choice and proportion of shafting keys and tolerances on key stock; development of standard formulas and procedure to be used in determining transmission shafting sizes.

R. R. Burkhalter

* BOLTS, NUTS, RIVETS, SCREWS, AND SIMILAR FASTENERS (B18)

Scope: Standardization of complete dimensional details required for the specification and manufacture of bolts, nuts, rivets, screws, and similar fasteners.

W. L. Barth, R. G. Cummings, R. R. Burkhalter, H. A. Marchant, K. G. Roth

* STANDARDIZATION OF WASHERS AND MACHINE RINGS (B27)

Scope: Development of product standards covering dimensions, physical properties, and tests for plain washers, lock washers, and retainer rings.

W. L. Barth, R. R. Burkhalter, H. A. Marchant

* TRANSMISSION CHAINS AND SPROCKET TEETH (B29)

Scope: Standardization of transmission chains and sprocket teeth of the roller, the inverted tooth (silent), and the detachable-link types.

G. Y. Anderson, Jr., D. C. Heitshu

* WIRE AND SHEET METAL GAGES (B32)

Scope: The standardization of a method of designating the diameter of metal and metal alloy wire, the thickness of metals and metal alloys in sheet, plate, and strip form and the wall thickness of tubing, piping, and casing made of these materials; and establishment of a standard series, or a number of standard series of nominal sizes and of tolerances for wires, sheets, plates, and strips.

J. Gurski, William Wiers

* CLASSIFICATION AND DESIGNATION OF SURFACE QUALITIES (B46)

Scope: Classification and designation of surfaces according to quality of surface.

W. L. Barth, Gustaf Carvelli

CLASSIFICATION OF MATERIALS FOR TOOLS, FIXTURES, AND GAGES (B52)

Scope: The establishment of a standard classification, based on performance requirements, of tool steels and other materials for tools, fixtures and gages.

L. A. Danse, (D. J. Giles, *Alt.*)

NUMBERING SYSTEM FOR ANTIFRICTION BEARINGS (B54)

Scope: A numbering system for the identification and classification of antifriction bearings.

G. N. Cole, H. N. Parsons

STANDARDIZATION OF V-BELTS AND V-BELT DRIVES (B55)

Scope: Standardization of dimensions and horsepower ratings of V-belts and sheaves for industrial and domestic use, excluding automotive and agricultural type.

S. E. Knudson

STORAGE BATTERIES (C40)

Scope: Definitions, classification, rating, and methods of test for storage batteries of the lead-acid and nickel-iron alkaline types, for stationary and for portable use.

L. E. Lighton

DEFINITIONS OF ELECTRICAL TERMS (C42)

Scope: Definitions of technical terms used in electrical engineering, including correlation of definitions and terms in existing standards.

L. Beltz

ELECTRIC WELDING APPARATUS (C52)

Scope: The formulation of standards for electric welding apparatus, including definitions of terms, classification, rating, heating, efficiency, testing methods, dielectric test, standard values of current and voltage, and name-plate data.

W. C. Schulte

RADIO ELECTRICAL COORDINATION (C63)

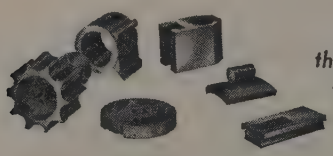
Scope: Development of definitions and methods of measurement of noise and signal

* Committee for which SAE is a sponsor.

OILITE may relieve your shortage of critical materials

Particularly in mass-production units of small and medium size, Oilite finished machine parts and bearings can be made to your design in a broad range of ferrous and nonferrous metals and alloys, except as limited by government control. Moreover, Oilite products of ferrous base may serve excellently instead of scarce nonferrous units or as replacements for steel and castings.

When you employ Oilite you also obtain the benefits of more than 20 years' engineering, research, and production experience in powder metallurgy, together with the service of field engineers throughout the United States and Canada.



You are invited to contact the field engineer in your district or write the home office regarding the application to your needs of Oilite products.

A Note to Executives

Oilite is an effective replacement, not a mere substitute

In the last decade, more and more executives have become "Oilite minded" because the advantages are many. To meet the current situation, many of our customers have changed their specifications to replace strategic copper and tin with products of iron powder or iron powder alloys. Others are replacing iron castings, steel and aluminum with similar Oilite products.

Also of importance to executives, under conditions of urgency, are the wide adaptability, the speed of delivery, and the economy of cost, time and manpower which result from the use of Oilite finished machine parts, made from metal powders.

Intricate designs, which normally require many different machining operations, can be produced quickly and economically from Oilite. There is great freedom of design and frequently two or more parts can be combined in a single Oilite unit. Oilite eliminates up to 24 machining operations.

Delivered ready for assembly, Oilite parts save the time and investment required to tool up by standard methods. It is not unusual to be in production on a complex Oilite part within a few weeks, as compared to a possible 18-month delivery of machine tools. Trained manpower is thus released for other urgent needs.

Oilite is not a substitute. It is metallurgy's answer to the need for a new material. It may solve your problem.

President

AMPLEX MANUFACTURING COMPANY

Subsidiary of Chrysler Corporation

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Field Engineers and Supply Depots in Principal U. S. and Canadian Cities

OILITE PRODUCTS

Heavy duty, oil-cushioned, self-lubricating bearings and finished machine parts in ferrous and nonferrous metals and alloys. Permanent filters. Friction units. Self-lubricating cored and bar stock.

OILITE
PRODUCTS

strengths, determination of levels of signal strength, levels of interfering sources, limiting ratio of noise to signal, and development of methods of control of influence, coupling, and susceptiveness.

P. J. Kent

PREFERRED VOLTAGES—100 VOLTS AND UNDER (C67)

Scope: Formulation of a list of preferred voltages—100 v and under, for generation from any source, and for distribution and utilization purposes; but excluding secondary voltages in reduced voltage motor starters.

L. H. Middleton, (F. A. Franklin *Alt.*)

INSPECTION REQUIREMENTS FOR MOTOR VEHICLES (D7)

Scope: Performance requirements and methods of testing with relation to the safe operation of motor vehicles on the highways of those parts and equipment, such as braking systems, steering mechanisms, lighting systems, frames, wheels, tires, other parts and equipment, the proper performance of which bears a distinct relationship to the safe operation of the motor vehicle.

T. C. Smith

RAILROAD HIGHWAY GRADE CROSSING PROTECTION (D8)

Scope: Standards for the construction, installation, and maintenance of warning signs, automatic and nonautomatic types, for use at railroad highway grade crossings.

V. J. Roper

LOADING PLATFORMS AT FREIGHT TERMINALS AND WAREHOUSES (E12)

Scope: Height of loading platforms to accommodate various classes of railroad cars and highway vehicles in relation to rail level and street or yard level; distance from track center to edge of loading platform; and vertical and horizontal clearances for highway vehicles.

John Walker, (B. F. Jones, *Alt.*)

SCIENTIFIC AND ENGINEERING SYMBOLS AND ABBREVIATIONS (Z10)

Scope: Standardization of letter symbols and signs for equations and formulas, and abbreviations for use in publications.

L. C. Lichty

PETROLEUM PRODUCTS AND LUBRICANTS (Z11)

Scope: Specifications, methods of test, and nomenclature relating to crude petroleum and petroleum products (products derived in whole or in large part from petroleum) other than asphalts, road oils, paint thinners, and electrical insulating materials.

J. M. Campbell, M. H. Young, A. W. Pope, Jr.

DRAWINGS AND DRAFTING ROOM PRACTICE (EXCLUSIVE OF ARCHITECTURAL DRAWINGS) (Z14)

Scope: Classification of and corresponding nomenclature of drawings in accordance with their purpose, method of representation of the subject, including arrangement of views and sections, use of lines of different kinds and thickness, indication of dimensions, tolerances, and fits, tapers and slopes, and surface or finish, symbols for elements, indication of materials by cross-hatching, arrangement of borderline, title, part list, notes, changes and revisions, method of folding and punching, kinds and sizes of lettering, figures and symbols, scales of reduction and enlargement, sizes of drawings and filing cabinets, width of rolls of paper and cloth, size of drafting equipment and tools, specifications of materials to be used for drawings and drafting; exclusive of architectural drawings.

O. E. Kirchner, W. A. Siler, (P. G. Clark, *Alt.*)

PREFERRED NUMBERS (Z17)

Scope: Development of a system of numbers in geometric series for use in standardization.

C. M. Larson

ACOUSTICAL MEASUREMENTS AND TERMINOLOGY (Z24)

Scope: Preparation of standards of terminology, units, scales, and methods of measurement in the fields of acoustics and mechanical vibration.

L. M. Ball, Paul Huber

SPECIFICATIONS AND METHODS OF TEST FOR SAFETY GLAZING MATERIAL (Z26)

Scope: Specifications and methods of test for safety glazing material (glazing material designed to promote safety and to reduce or minimize the likelihood of personal injury from flying glazing material when the glazing material is broken) as used for all purposes, including windshields and windows of motor vehicles, motorboats, and aircraft; and bulletproof windows and partitions.

J. L. McCloud, B. F. Jones, H. C. Mougey, R. E. VanDeventer

Coordinating Research Council, Inc.

SAE and the American Petroleum Institute jointly organized the Coordinating Research Council, Inc. in 1942. Object of the CRC is to encourage and promote the arts and sciences by directing scientific cooperative research in developing the best combinations of fuels, lubricants, and equipment powered by internal-combustion engines; and to afford means of cooperation with the government on matters of national interest within this field.

In the course of research sponsored by the two technical committees of the Council (the Coordinating Fuel and Equipment Research Committee and Coordinating Lubricants and Equipment Research Committee) a number of research techniques have been developed. Those considered suitable for standardization have been referred to the American Society for Testing Materials.

Information on the work of the technical committees, may be secured from the Coordinating Research Council, Inc., 30 Rockefeller Plaza, New York 20, N. Y.

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P. J. Kent, W. F. Little, V. J. Roper

TAP-LOK INSERTS* and GROOV-PIN PRESS FIT FASTENERS

TAP-LOK INSERTS

TAP-LOK Inserts provide a durable threaded surface in materials of low shearing strength such as plastics, wood, light metals, etc. They afford secure anchorages for screws, studs and other threaded parts under stress loads and eliminate the danger of thread stripping in assembling and service.

Each Insert taps into a hole of the same size as the tap drill hole for the external thread of the Insert. A special driving tool is used to seat the Insert in the boss. As the Insert turns, it taps its own thread with the edges of its slotted segments, which are forced inward slightly in tapping. As the screw fastener passes into the slotted area, the outward pressure on the Insert tends to lock it firmly in the boss. Tap-Lok Inserts improve and safeguard assemblies — help reduce the scrap factor — reduce costs. Send for samples and literature.

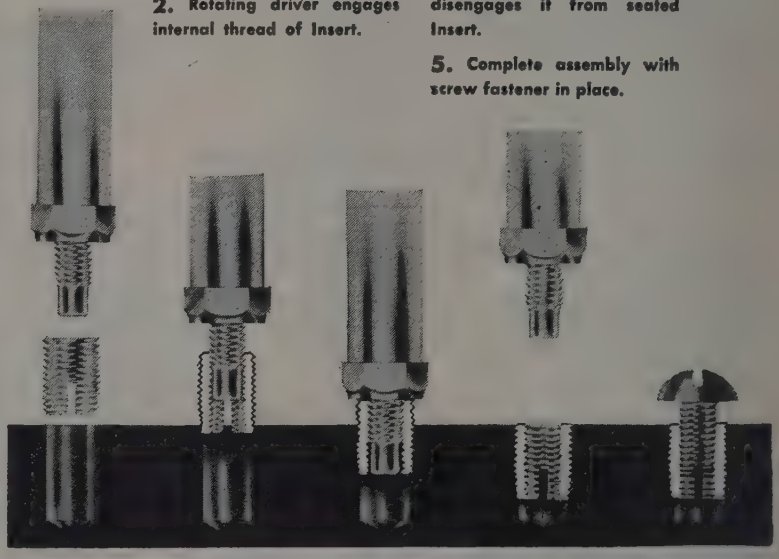
1. Insert is placed in position under driver.

2. Rotating driver engages internal thread of Insert.

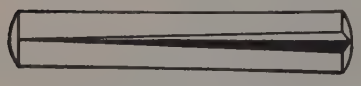
3. After driver is fully engaged, Insert is driven into hole.

4. Reverse torque on driver disengages it from seated Insert.

5. Complete assembly with screw fastener in place.

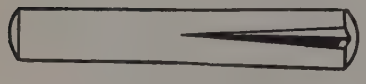


GROOV-PIN PRESS FIT FASTENERS



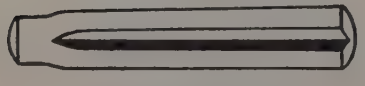
Full Length Taper Groov-Pin

Half Length Reverse Taper Groov-Pin

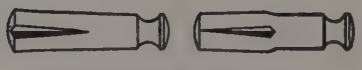


Half Length Taper Groov-Pin

Center Groov-Pin



Full Length Parallel Groov-Pin



Half Length Taper and Reverse Taper Groov-Pins with Annular Grooves for Spring Retention.

GROOV-PINS are essentially cylindrical pins with longitudinal grooves. They are made of cold rolled steel, bar or coil stock—alloys upon specification. The grooves are rolled or pressed into the cylindrical body to deform the pin stock within controlled limits. Forcing the pin into a straight hole causes the displaced material to flow back and effect a locking fit within the pin's elastic range. It requires no tapping, reaming or other preparation of the hole, is easy to start and assemble, has extraordinary holding power and may be reused repeatedly.

Groov-Pins have simplified design and reduced assembly costs for many years for manufacturers of automobiles, aircraft, machinery, appliances, instruments and many other products. Send for samples and literature.

* Reg. U. S. Pat. Off.

GROOV-PIN CORPORATION 2011 KERRIGAN AVENUE UNION CITY, NEW JERSEY

SAE Technical Board Rules and Regulations

1. Objective

The objective of the Board is to make the knowledge, experience, and skill of automotive engineers on technical problems adapted to cooperative committee action, effectively useful to industry, government, educational institutions, the public, and the profession, and to enhance the value of Society membership by the benefits which technical committee activity brings to those who participate in it.

2. Responsibility of Board Members

In discharging their responsibilities, the members of the Board and the members of the committees under its jurisdiction, function independently as individuals, and not as agents or representatives of the organizations by which they are or may be employed.

3. Powers and Duties

(a) The Board is the agent of the SAE Council with full authority to direct and supervise all technical committee activities of the Society, including its participation in the technical committee activity of other organizations; subject only to the right of appeal to the Council in the event of disagreement with an action of the Board.

(b) The Board will determine what projects are to be undertaken and will define their scope.

(c) The Board will determine what engineering relationships involving technical committee activity are to be undertaken for, or in cooperation with government, industry, other technical societies, educational institutions, and civic organizations.

(d) The Board will organize such committees as may be needed to carry on the Board's projects, and will appoint Society representatives on the technical committees of other organizations in which the Society may participate.

(e) The Board will steer and review the work of its committees and of its representatives on the technical committees of other organizations.

(f) The Board will approve, and in the name of the Society, issue technical reports, including standards and recommended practices, which result from the work of its committees and will act for the Society on reports which result from the work of technical committees of other organizations in which the Society is a participant.

4. Technical Committees

(a) The Board will organize such technical committees as are necessary to carry on its projects and will approve the initial membership of such committees. Thereafter, the sponsor of a committee, or the chairman of a committee if there is no sponsor, is authorized to effect changes in the personnel of a committee. The chairmen of technical committees shall be designated by the Board and at least once each year each committee shall nominate a chairman for Board approval.

(b) The Board will define the scope of each committee, and all projects within the scope of a committee shall be referred to it.

(c) The function of a committee shall be to advise the Board on matters within its scope; to direct and administer projects within its scope; and to cooperate with other committees on matters of joint interest.

(d) Members of SAE Technical Committees shall be appointed on the basis of their personal qualifications and consequent ability to contribute to the work of such committees. Invitations to serve on SAE Technical Committees shall call attention of appointees to Section 2 of these Rules and Regulations.

(e) Where a government or other agency requests participation in SAE committee work through an individual of its own selection, such individual may be appointed as a consultant or liaison representative without vote. Where the individual qualifies under Section 4(d), he may be appointed to committee membership with the understanding that he will function as an individual.

5. Sponsors

(a) The Board may designate one or more of its members to sponsor any committee.

(b) The duties of the sponsor (or sponsors) shall include liaison between the Board and the committee, advising the Board with respect to committee personnel, and expediting the work.

6. Committee Procedures

(a) Committees may appoint steering committees from their membership.

(b) Committees may appoint subcommittees to handle detail phases of their work. Nonmembers of a committee may be appointed to such subcommittees.

(c) Committees may initiate new projects within their scopes; provided that prompt notice shall be given the Board of all self-initiated new projects; and provided that where such new projects involve relations with other organizations, such relations shall have the approval of the Board.

(d) Only members of a committee shall vote or cast letter ballots.

(e) Committees may hold executive sessions, provided that any member of the Society shall be granted a hearing on any matter before a committee.

(f) Where a committee has reason to believe that a proposed project may involve the Society in a jurisdictional conflict with another organization, before undertaking such project, the committee shall refer the matter to the Board for review and instructions.

7. Committee Reports

(a) Reports of committees submitted to the Board for approval in general should have the unanimous approval of the committee. Where unanimous approval cannot be achieved, the report shall have the approval of at least two-thirds of the members of the committee and shall set forth dissenting views, including the dissenting views of nonmembers of the committee who may have been consulted. The Board may eliminate such dissenting views from the report as finally issued.

(b) Reports of committees submitted for final approval at a meeting of the Board shall be distributed to the Board members at least two weeks before the meeting; otherwise, any action on such reports at the meeting of the Board will require confirmation by letter ballot.

(c) Every report approved and issued by the Board shall carry the following statement:

"All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no

answers to BEARING questions--

free

DATA SHEETS are being produced monthly by Johnson Bronze engineers...twenty sheets now available . . . more to come. They cover bearing types, bearing design, materials, powder metallurgy, tolerances, tests, lubrication, etc. They contain valuable information for users of bearings and design engineers. These data sheets are printed in 8½x11 inch size for your convenience in filing. Write today for your set.

***You** will find Johnson Engineers willing to help you decide which type bearing is best suited and to design it for the application. As we manufacture all types of sleeve bearings, we base all of our recommendations on facts, free from prejudice.*

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SLEEVE BEARING HEADQUARTERS

625 SOUTH MILL STREET • NEW CASTLE, PA.

SAE Technical Board Rules and Regulations (*Continued*)

agreement to adhere to any SAE Standard or SAE Recommended Practice, and no commitment to conform to or be guided by any technical report.

"In formulating and approving technical reports, the Board and its committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents."

8. Standards and Recommended Practices

(a) Reports of committees recommending the approval of standards and recommended practices shall represent a consensus of those substantially concerned, including prospective producers and users of the proposed standard or recommended practice.

(b) SAE Standards shall be based on sound, established engineering practice.

(c) SAE Recommended Practices shall be based on sound engineering principles and shall be intended as guides toward standard engineering practice.

9. Board Approval of Reports

(a) The Board may approve and authorize the issuance of technical reports by voice vote at a meeting or by letter ballot.

(b) The Board will strive for unanimous approval, but in no case will it approve or authorize the issuance of a report which has not been approved by three-quarters of the members of the entire Board. The Chairman may declare a report submitted to letter ballot to have been approved by the Board after three weeks from date of circulation of the report to the Board; provided ballots have been returned by at least three-quarters of the members of the Board; and provided that no negative ballots have been returned. Upon presentation by a Board member of a written dissenting report within three weeks after the distribution of a proposed report, the proposal shall be reconsidered by the Board before final action.

(c) The board will not alter the technical content of a committee report without first referring it back to the responsible committee.

10. Board Meetings

(a) Only members of the Board have the right to attend and vote at Board meetings, and to cast letter ballots. Others may attend at the discretion of the Board.

(b) The Chairman of the Board shall preside at meetings of the Board, and if he is not present, a member of the Executive Committee designated by that Committee or by the Chairman, shall preside.

(c) One-half the members of the Board shall constitute a quorum.

(d) Action by the Board shall be by majority vote of those present; provided that any member may call for a letter ballot on action taken and when letter ballot is taken, action by the Board shall be by majority vote of the entire Board; and provided further that Section 9 shall govern the approval and issuance of reports.

(e) The first order of business shall be an executive session.

(f) When questions of parliamentary procedure arise, they shall be determined by Robert's Rules of Order.

(g) The last order of business shall be the determination of the time and place of the next meeting of the Board; provided that the Board may authorize its Executive Committee to determine the time and place of its next meeting.

11. Executive Committee

(a) At the Board's first meeting in each calendar year, the Chairman of the Board shall nominate for Board approval five members of the Board to serve with him as the Executive Committee of the Board for one year. The Chairman of the Board shall be the Chairman of the Executive Committee.

(b) The Executive Committee shall be the executive and administrative agent of the Board and, on matters requiring prompt disposition which arise between meetings of the Board, shall exercise all powers of the Board, except the approval and issuance of reports. The Executive Committee shall promptly notify the Board of all actions taken. Actions of the Executive Committee shall be subject to the review and approval of the Board.

(c) In intervals between meetings of the Board, the Executive Committee shall place before the Board any question on which a Board member desires the opinion of or action by the entire Board.

12. Secretary of the Board

(a) The Secretary of the Board and his staff assistants shall be designated by the General Manager of the Society.

(b) The Secretary shall be responsible for the performance of such staff functions as the Board or its Executive Committee may direct, and shall provide for the recording of minutes of meetings of the Board, its committees and subcommittees, and for their distribution, subject to the financial limitations imposed by the budget approved by the Council for the operations of the Board.

(c) Unless the Board specifically directs otherwise, the Secretary shall have authority to release information and publicity with respect to the work of the Board and its committees.

(d) Committees may make no commitments involving expenditure of Society funds without the approval of the Secretary.

(e) The Secretary may approve the payment by the Society of necessary and reasonable expenses of any officer or regular employee of the Government, or any professor or instructor of a recognized educational institution incurred in travelling to, attending, and returning from a meeting of the Board or of its committees or subcommittees, either as a member of any of these groups or as an invited consultant.

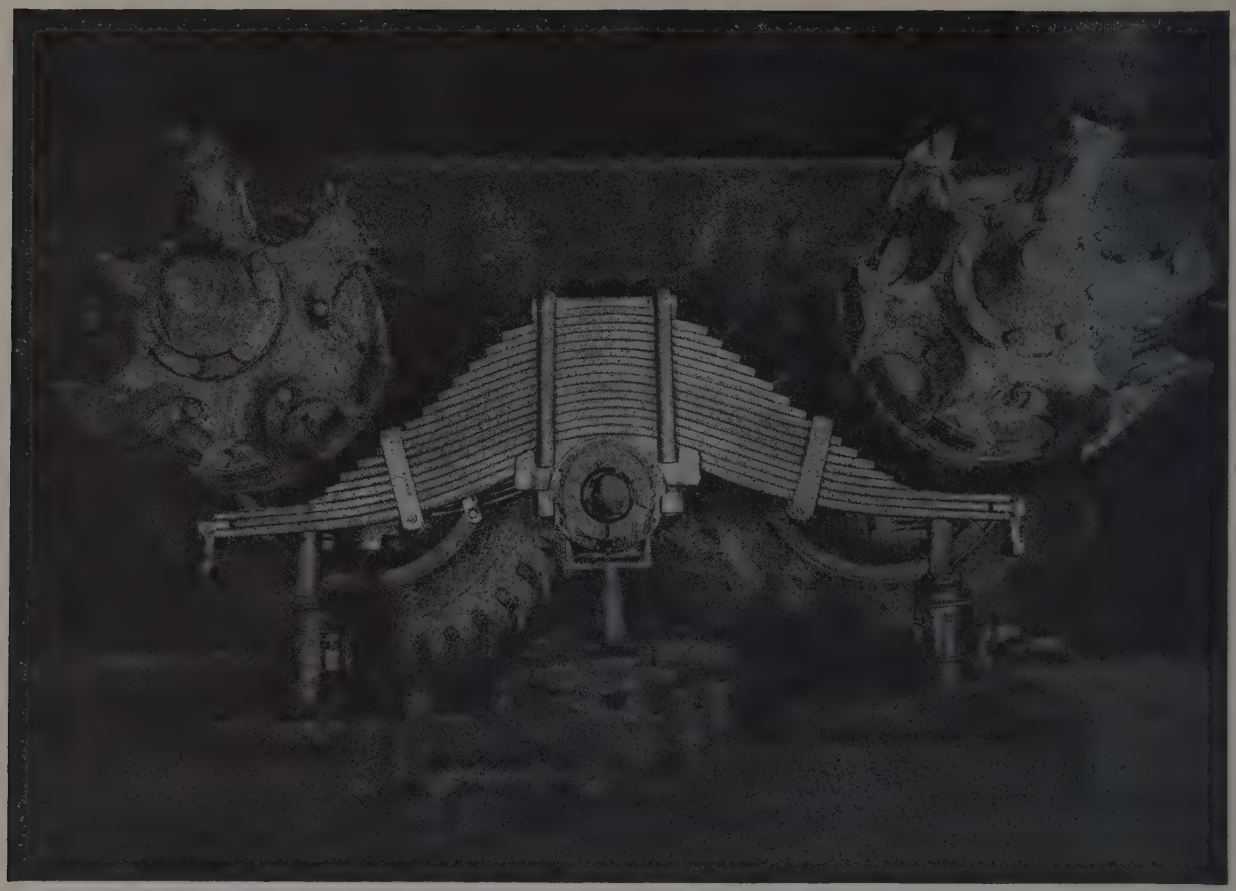
13. Records

(a) The records of the Board and its committees and subcommittees, including minutes and their appendixes of all meetings, shall be maintained in the offices of the Society where they will be available for inspection except as the Board directs otherwise.

14. Amendments

(a) Amendments to these rules and regulations shall be approved by not less than three-quarters of the members of the Board.

Adopted January 10, 1946 and last revised January 12, 1950.



It doesn't pay to overgrade in selecting spring steels

In selecting spring steels it is generally considered sound practice to use grades whose alloy content is consistent with the thickness of the finished spring section. Springs of heavy section, for instance, usually require steel fairly rich in alloy content while those relatively light in section can be made economically from steel of medium or low alloy content.

But light or heavy, lean or rich, there are three properties that all spring steels must have for good results: superior impact value; excellent fatigue-resistance; and high yield point. A proper balance of these properties is needed to satisfy the mass requirements of the section as well as satisfactory response to heat treatment.

There is no short cut to economical selection of spring steels. It takes study and experience with various analyses and heat treatments. In this connection our metallurgists will be glad to help you arrive at the most economical solution. They will give unbiased advice based on long experience with all types of spring steels.

We manufacture the entire range of AISI steels as well as special grades and carbon steels.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

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BETHLEHEM STEEL

BETHLEHEM ALLOY STEELS

Selection and Use of Steels

SAE General Information

Report of Iron and Steel Division approved June 1911 and last revised by Iron and Steel Technical Committee October 1947.

[*SAE Specifications for automotive steels are developed cooperatively by steel producers and users.*

History of standardized automotive steels goes back to Bulletin No. 9 of the Mechanical Branch of the Association of Licensed Automobile Manufacturers, dated Dec. 23, 1905, which have ALAM Specifications Nos. 1 through 6 for steels. ALAM Bulletin No. 13 soon followed with specifications for steel and gray iron castings, notes on malleable iron castings, and a standard for arbitration bars and test specimens for the iron castings.

In 1910, SAE took over ALAM's standardization work, setting up the SAE Standards Committee and, under it, the SAE Iron and Steel Division (now the SAE Iron and Steel Technical Committee). SAE Standards and SAE Recommended Practices developed by this group have been of such engineering and commercial value that for many years they have been used in nearly all fields of mechanical manufacture in the United States and many other countries.]

Steel compositions included in SAE Handbook are considered adequate for practically all parts made of wrought ferrous materials that are necessary for the production of automotive apparatus, and include grades that have been found commercially available and technically adequate for the service required of such parts. (SAE steel compositions should not be confused with specifications, of which composition is only a part.)

Definite applications of SAE steels are not included, because—as it will be readily appreciated—the selection of a steel for a given part must be based upon an intimate knowledge of a number of important factors such as the availability and cost of the material, the detail design of the part, and the severity of the service to be imposed, whether the part is to be forged or machined, and its machinability. It is only after a careful consideration of these factors that steels for the great variety of automotive and other mechanical parts can be selected properly. Only general applications of the SAE steels are indicated.

It is important to bear in mind that the information pertaining to typical heat-treatments is based on the tests and experience of steel manufacturers and users and is intended only as a guide in selecting steels and their heat-treatment. Care has been taken to provide reliable data, but steel users should supplement these data with suitable inspection tests and practices in order to be assured that each lot of material purchased will respond in a normal manner to the heat-treatment generally applied in their particular practices.

Variations in the effect of the usual forms of heat-treatment may be due to personnel, variations in the steel composition or manufacture, and to changes in local conditions such as control and precision of heat-treating equipment. In order to minimize the effects of such variations, steel users should keep the product of each mill heat of steel separate in the stock room and during processing so that necessary adjustments of treatment can be made.

When selecting a steel, the user should always keep in mind the importance of obtaining the desired strength and hardness without the necessity of resorting to drastic forms of quenching. Water and brine quenching may be considered as drastic treatments when applied to carbon steels and simple alloy steels containing more than 0.35% carbon. Oil quenching minimizes distortion, whereas water and brine accentuate it. Drastic quenching, improperly applied, may lead to serious cracking or spalling. Frequently the necessity for drastic quenching can be avoided by proper control of hardenability. Such discretion is especially important in the case of parts of intricate shape and with abrupt changes in section. This caution is not intended to condemn the practice of water or brine quenching altogether as there are frequent instances where the desired hardness can be obtained in no other manner. It is intended as a warning to the uninitiated to proceed with caution until the necessary experience and skill have been acquired.

Another detail of greatest importance to the designer and the producer of heat-treated steel parts is correct filleting. Sharp corners and inadequate fillets are the primary cause of most fatigue failures. In parts subjected to dynamic stresses, sharp corners and inadequate fillets produce serious stress concentration, causing the actual service stresses to build up to a point where they may amount to several times the normal working stress calculated by the designer. The use of generous fillets is especially desirable with all high-strength alloy steels.

While adequate fillets may reduce the weakening effect of abrupt changes in section, they will not appreciably reduce the serious distortion which inevitably develops when parts of widely varying section are quenched during heat-treatment. Whether oil or water quenching is required, heavy sections cool less rapidly than light sections and tend to produce distortions. Consequently it is desirable to minimize variations in section as much as practicable.

The steel user should also remember that the elastic deflection under load of a given part is a function of the section of the part rather than of the composition, heat-treatment, or hardness of the particular steel that may be used. In other words, the modulus of elasticity of all the commercial steels, both plain carbon and alloy types, is the same so far as practical designing is concerned. Consequently if a part deflects excessively within the elastic range, the remedy lies in the field of design, not in the field of metallurgy. Either a heavier section must be used, the points of support must be increased, or some similar change made, since under the same conditions of loading all steels deflect the same amount within the elastic limit.

SAE Numbering System for Wrought or Rolled Steel

SAE Standard

Report of Iron and Steel Division approved January 1912 and last revised October 1947.

Only compositions which conform to the SAE compositions given in the current SAE Handbook should bear the prefix "SAE."

A numeral index system is used to identify the compositions of the SAE steels, which system makes possible use of numerals on shop drawings and blueprints to describe partially the composition of the material.

In the original conception, the first digit indicated the type to which the steel belonged; thus "1-" indicated a carbon steel; "2-" a nickel steel; and "3-" a nickel-chromium steel. In the case of the simple alloy steels, the second digit generally indicated the approximate percentage of the predominant alloying element. Usually the last two or three digits indicated the approximate average carbon content in "points" or hundredths of one per cent. Thus "2340" indicated a nickel steel of approximately 3% nickel and (3.25 to 3.75%) and 0.40% carbon (0.38 to 0.43%).

In some instances, in order to avoid confusion, it has been found necessary to depart from this system of identifying the approximate alloy composition of a steel by varying the second and third digits of the number. Instances of such departure are the steel numbers selected for several of the corrosion- and heat-resisting alloys and the triple alloy steels.

The basic numerals for the various types of SAE Steel are given in Table 1.

TABLE 1—*Basic Numerals for SAE Steels*

TYPE OF STEEL AND AVERAGE CHEMICAL CONTENTS IN %	NUMERALS AND DIGITS
Carbon Steels	1xxx
Plain Carbon	10xx
Free Cutting (screw stock)	11xx
Manganese Steels	13xx
Mn 1.75	
Nickel Steels	2xxx
Ni 3.50	23xx
Ni 5.00	25xx
Nickel-Chromium Steels	3xxx
Ni 1.25; Cr 0.65 or 0.80	31xx
Ni 3.50; Cr 1.55	33xx
Corrosion- and Heat-Resisting	303xx
Molybdenum Steels	40xx
Mo 0.25	
Chromium-Molybdenum Steels	41xx
Cr 0.50 and 0.95; Mo 0.25 and 0.20	
Nickel-Chromium-Molybdenum Steels	
Ni 1.80; Cr 0.50 and 0.80; Mo 0.25	43xx
Ni 0.55; Cr 0.50; Mo 0.20	86xx
Ni 0.55; Cr 0.50; Mo 0.25	87xx
Ni 3.25; Cr 1.20; Mo 0.12	93xx
Ni 0.45; Cr 0.40; Mo 0.12	94xx
Ni 0.55; Cr 0.17; Mo 0.20	97xx
Ni 1.00; Cr 0.80; Mo 0.25	98xx
Nickel-Molybdenum Steels	
Ni 1.55 and 1.80; Mo 0.20 and 0.25	46xx
Ni 3.50; Mo 0.25	48xx
Chromium Steels	5xxx
Low Cr—Cr 0.27 and 0.65	50xx
Low Cr—Cr 0.80, 0.95, or 1.05	51xx
Low Cr (bearing) Cr 0.50	501xx
Medium Cr (bearing) Cr 1.00	511xx
High Cr (bearing) Cr 1.45	521xx
Corrosion- and Heat-Resisting	514xx and 515xx
Chromium-Vanadium Steel	61xx
Cr 0.95; V 0.15 min.	
Silicon-Manganese Steels	9xxx
Mn 0.65 and 0.85; Si 1.40 and 2.00	92xx
Low-Alloy, High-Tensile	950
Castings, Steel	
Corrosion-Resistant	60xxx
Heat-Resistant	70xxx
Carbon and Low Alloy	0x0
	00xx
High-Strength	01xx

Chemical Compositions of SAE Carbon Steels

SAE Standard

From report of Iron and Steel Division approved June 1911 and last revised by Iron and Steel Technical Committee January 1951.

[In 1941, the SAE Iron and Steel Division in collaboration with the American Iron and Steel Institute made a major change in the method of expressing composition ranges for the SAE steels. The plan, as now applied, is based in general on narrower ladle analysis ranges plus certain check analysis allowances on individual samples, in place of the fixed ranges and limits without tolerances formerly provided for carbon and other elements in SAE steels. No changes in compositions or additions or deletions of numbers

TABLE 1a—*Carbon Steel Compositions Applicable Only to Semi-Finished Products for Forging, to Hot-Rolled and Cold-Finished Bars, to Wire Rods, and to Seamless Tubing*

SAE Number	LADLE CHEMICAL COMPOSITION[a] LIMITS, %				CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	
1006	0.08 max	0.25–0.40	0.040	0.050	C1006
1008	0.10 max	0.25–0.50	0.040	0.050	C1008
1010	0.08–0.13	0.30–0.60	0.040	0.050	C1010
1015	0.13–0.18	0.30–0.60	0.040	0.050	C1015
1016	0.13–0.18	0.60–0.90	0.040	0.050	C1016
1017	0.15–0.20	0.30–0.60	0.040	0.050	C1017
1018	0.15–0.20	0.60–0.90	0.040	0.050	C1018
1019	0.15–0.20	0.70–1.00	0.040	0.050	C1019
1020	0.18–0.23	0.30–0.60	0.040	0.050	C1020
1021	0.18–0.23	0.60–0.90	0.040	0.050	C1021
1022	0.18–0.23	0.70–1.00	0.040	0.050	C1022
1024	0.19–0.25	1.35–1.65	0.040	0.050	C1024
1025	0.22–0.28	0.30–0.60	0.040	0.050	C1025
1026	0.22–0.28	0.60–0.90	0.040	0.050	C1026
1027	0.22–0.29	1.20–1.50	0.040	0.050	C1027
1030	0.28–0.34	0.60–0.90	0.040	0.050	C1030
1033	0.30–0.36	0.70–1.00	0.040	0.050	C1033
1034	0.32–0.38	0.50–0.80	0.040	0.050	C1034
1035	0.32–0.38	0.60–0.90	0.040	0.050	C1035
1036	0.30–0.37	1.20–1.50	0.040	0.050	C1036
1038	0.35–0.42	0.60–0.90	0.040	0.050	C1038
1039	0.37–0.44	0.70–1.00	0.040	0.050	C1039
1040	0.37–0.44	0.60–0.90	0.040	0.050	C1040
1041	0.36–0.44	1.35–1.65	0.040	0.050	C1041
1042	0.40–0.47	0.60–0.90	0.040	0.050	C1042
1043	0.40–0.47	0.70–1.00	0.040	0.050	C1043
1045	0.43–0.50	0.60–0.90	0.040	0.050	C1045
1046	0.43–0.50	0.70–1.00	0.040	0.050	C1046
1049	0.46–0.53	0.60–0.90	0.040	0.050	C1049
1050	0.48–0.55	0.60–0.90	0.040	0.050	C1050
1052	0.47–0.55	1.20–1.50	0.040	0.050	C1052
1055	0.50–0.60	0.60–0.90	0.040	0.050	C1055
1060	0.55–0.65	0.60–0.90	0.040	0.050	C1060
1062	0.54–0.65	0.85–1.15	0.040	0.050	C1062
1064	0.60–0.70	0.50–0.80	0.040	0.050	C1064
1065	0.60–0.70	0.60–0.90	0.040	0.050	C1065
1066	0.60–0.71	0.85–1.15	0.040	0.050	C1066
1070	0.65–0.75	0.60–0.90	0.040	0.050	C1070
1074	0.70–0.80	0.50–0.80	0.040	0.050	C1074
1078	0.72–0.85	0.30–0.60	0.040	0.050	C1078
1080	0.75–0.88	0.60–0.90	0.040	0.050	C1080
1085	0.80–0.93	0.70–1.00	0.040	0.050	C1085
1086	0.82–0.95	0.30–0.50	0.040	0.050	C1086
1090	0.85–0.98	0.60–0.90	0.040	0.050	C1090
1095	0.90–1.03	0.30–0.50	0.040	0.050	C1095

[a] Where silicon is required, the following limits and ranges are commonly used for basic open-hearth steel grades: for steel designations up to but excluding SAE 1015, 0.10% maximum; for SAE 1015 to SAE 1025, 0.10% maximum or ranges of 0.10 to 0.20% or 0.15 to 0.30%; for over SAE 1025, ranges of 0.10 to 0.20% or 0.15 to 0.30%.

TABLE 1b—*Carbon Steel Compositions Applicable Only to Structural Shapes, Plates, Strip, Sheets, and Welded Tubing*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %			
	C	Mn	Maximum P	Maximum S
1006	0.08 max	0.25–0.45	0.040	0.050
1008	0.10 max	0.25–0.50	0.040	0.050
1010	0.08–0.13	0.30–0.60	0.040	0.050
1015	0.12–0.19	0.30–0.60	0.040	0.050
1016	0.12–0.19	0.60–0.90	0.040	0.050
1017	0.14–0.21	0.30–0.60	0.040	0.050
1018	0.14–0.21	0.60–0.90	0.040	0.050
1019	0.14–0.21	0.70–1.00	0.040	0.050
1020	0.17–0.24	0.30–0.60	0.040	0.050
1021	0.17–0.24	0.60–0.90	0.040	0.050
1022	0.17–0.24	0.70–1.00	0.040	0.050
1024	0.18–0.26	1.30–1.65	0.040	0.050
1025	0.21–0.28	0.30–0.60	0.040	0.050
1026	0.21–0.28	0.60–0.90	0.040	0.050
1027	0.21–0.29	1.20–1.55	0.040	0.050
1030	0.27–0.35	0.60–0.90	0.040	0.050
1033	0.29–0.37	0.70–1.00	0.040	0.050
1034	0.31–0.39	0.50–0.80	0.040	0.050
1035	0.31–0.39	0.60–0.90	0.040	0.050
1036	0.29–0.38	1.20–1.55	0.040	0.050
1038	0.34–0.43	0.60–0.90	0.040	0.050
1039	0.36–0.45	0.70–1.00	0.040	0.050
1040	0.36–0.45	0.60–0.90	0.040	0.050
1041	0.35–0.45	1.30–1.65	0.040	0.050
1042	0.39–0.48	0.60–0.90	0.040	0.050
1043	0.39–0.48	0.70–1.00	0.040	0.050
1045	0.42–0.51	0.60–0.90	0.040	0.050
1046	0.42–0.51	0.70–1.00	0.040	0.050
1049	0.45–0.54	0.60–0.90	0.040	0.050
1050	0.47–0.56	0.60–0.90	0.040	0.050
1052	0.46–0.56	1.20–1.55	0.040	0.050
1055	0.50–0.60	0.60–0.90	0.040	0.050
1060	0.54–0.66	0.60–0.90	0.040	0.050
1062	0.53–0.66	0.85–1.15	0.040	0.050
1064	0.59–0.71	0.50–0.80	0.040	0.050
1065	0.59–0.71	0.60–0.90	0.040	0.050
1066	0.59–0.72	0.85–1.15	0.040	0.050
1070	0.64–0.76	0.60–0.90	0.040	0.050
1074	0.68–0.80	0.50–0.80	0.040	0.050
1078	0.71–0.86	0.30–0.60	0.040	0.050
1080	0.74–0.89	0.60–0.90	0.040	0.050
1085	0.79–0.94	0.70–1.00	0.040	0.050
1086	0.81–0.96	0.30–0.50	0.040	0.050
1090	0.84–0.99	0.60–0.90	0.040	0.050
1095	0.89–1.04	0.30–0.50	0.040	0.050

are made by either AISI or SAE without first informing the other of the proposed changes and holding open discussion between both groups in order to effect simultaneous changes.]

The nominal chemical limits or ranges in the compositions given in Tables 1a, 1b, and 2 are subject to standard variations in check analysis given in the SAE Standard on Permissible Variations from Specified Chemical Ranges and Limits for Steels.

Compositions given in Table 1a are applicable only to semi-finished products for forging, to hot-rolled and cold-finished bars, to wire rods, and to seamless tubing.

Compositions given in Table 1b are applicable only to structural shapes, plates, strip, sheets, and welded tubing.

Free-cutting steels are basic open-hearth and acid-bessemer resulfurized carbon steels. Compositions given in Table 2 are applicable only to semi-finished products for forging, to hot-rolled and cold-finished bars, and to wire rods.

TABLE 2—*Free-Cutting Steel Compositions*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %				CORRESPONDING AISI NUMBER
	C	Mn	P	S	
Bessemer					
1111	0.13 max	0.60–0.90	0.07–0.12	0.08–0.15	B1111[a]
1112	0.13 max	0.70–1.00	0.07–0.12	0.16–0.23	B1112[a]
1113	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	B1113[a]
Open Hearth			*Maximum*		
1109	0.08–0.13	0.60–0.90	0.040	0.08–0.13	C1109
1114	0.10–0.16	1.00–1.30	0.040	0.08–0.13	C1114
1115	0.13–0.18	0.60–0.90	0.040	0.08–0.13	C1115
1116	0.14–0.20	1.10–1.40	0.040	0.16–0.23	C1116
1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13	C1117
1118	0.14–0.20	1.30–1.60	0.040	0.08–0.13	C1118
1119	0.14–0.20	1.00–1.30	0.040	0.24–0.33	C1119
Open Hearth Cont'd			*Maximum*		
1120	0.18–0.23	0.70–1.00	0.040	0.08–0.13	C1120
1126	0.23–0.29	0.70–1.00	0.040	0.08–0.13	C1126
1132	0.27–0.34	1.35–1.65	0.040	0.08–0.13	C1132
1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13	C1137
1138	0.34–0.40	0.70–1.00	0.040	0.08–0.13	C1138
1140	0.37–0.44	0.70–1.00	0.040	0.08–0.13	C1140
1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13	C1141
1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33	C1144
1145	0.42–0.49	0.70–1.00	0.040	0.04–0.07	C1145
1146	0.42–0.49	0.70–1.00	0.040	0.08–0.13	C1146
1151	0.48–0.55	0.70–1.00	0.040	0.08–0.13	C1151

[a] Because of the technological nature of the process, acid bessemer steels are not furnished with specified silicon content. When silicon is required, the following limits and ranges are commonly used for basic open-hearth steel grades: for steel designations up to but excluding SAE 1114, 0.10% maximum; for SAE 1114 and over, 0.10 maximum or the ranges of 0.10 to 0.20% or 0.15 to 0.30%.

Chemical Compositions of SAE Alloy Steels

SAE Standard

From report of Iron and Steel Division approved June 1911 and last revised by Iron and Steel Technical Committee January 1950.

[*In 1941, the SAE Iron and Steel Division in collaboration with the American Iron and Steel Institute made a major change in the method of expressing composition ranges for the SAE steels. The plan as now applied is based in general on narrower ladle analysis ranges plus certain check analysis allowances on individual samples, in place of the fixed ranges and limits without tolerances formerly provided for carbon and other elements in SAE steels. No changes in compositions or additions or deletions of numbers are made by either AISI or SAE without first informing the other of the proposed changes and holding open discussion between both groups in order to effect simultaneous changes*].

The compositions in this Standard may apply to either open-hearth or electric-furnace steels. Where they apply to electric-furnace steels, the maximum phosphorus and maximum sulfur shall each be 0.025%. The nominal chemical limits or ranges in the compositions given in Tables 1 to 11 inclusive are subject to standard variations in check analysis given in the SAE Standard on Permissible Variations from Specified Chemical Ranges and Limits for Steels.

Tables 1 through 11 are applicable to billets, blooms, slabs, and hot-rolled and cold-rolled bars.

TABLE 1—*Manganese Steels*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %					CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	
1320	0.18–0.23	1.60–1.90	0.040	0.040	0.20–0.35	1320
1330	0.28–0.33	1.60–1.90	0.040	0.040	0.20–0.35	1330
1335	0.33–0.38	1.60–1.90	0.040	0.040	0.20–0.35	1335
1340	0.38–0.43	1.60–1.90	0.040	0.040	0.20–0.35	1340

TABLE 2—*Nickel Steels*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %						CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Ni	
2317	0.15–0.20	0.40–0.60	0.040	0.040	0.20–0.35	3.25–3.75	2317
2330	0.28–0.33	0.60–0.80	0.040	0.040	0.20–0.35	3.25–3.75	2330
2340	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	3.25–3.75	2340
2345	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	3.25–3.75	2345
2512[a]	0.09–0.14	0.45–0.60	0.025	0.025	0.20–0.35	4.75–5.25	E2512
2515	0.12–0.17	0.40–0.60	0.040	0.040	0.20–0.35	4.75–5.25	2515
2517[a]	0.15–0.20	0.45–0.60	0.025	0.025	0.20–0.35	4.75–5.25	E2517

[a] Electric-furnace steel.

Where the tables show no letter prefix to the AISI number, the steel is predominantly open hearth.

For standard variations in composition limits, refer to Table 4 of the SAE Standard on Permissible Variations from Specified Chemical Ranges and Limits for Steels.

TABLE 3—*Nickel-Chromium Steels*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %							CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Ni	Cr	
3115	0.13–0.18	0.40–0.60	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	3115
3120	0.17–0.22	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	3120
3130	0.28–0.33	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	3130
3135	0.33–0.38	0.60–0.80	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	3135
3140	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.55–0.75	3140
3145	0.43–0.48	0.70–0.90	0.040	0.040	0.20 0.35	1.10–1.40	0.70–0.90	3145
3150	0.48–0.53	0.70–0.90	0.040	0.040	0.20–0.35	1.10–1.40	0.70–0.90	3150
3310[a]	0.08–0.13	0.45–0.60	0.025	0.025	0.20–0.35	3.25–3.75	1.40–1.75	E3310
3316[a]	0.14–0.19	0.45–0.60	0.025	0.025	0.20–0.35	3.25–3.75	1.40–1.75	E3316

[a] Electric-furnace steel.

TABLE 4—*Molybdenum Steels*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %						CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Mo	
4017	0.15–0.20	0.70–0.90	0.040	0.040	0.20–0.35	0.20–0.30	4017
4023	0.20–0.25	0.70–0.90	0.040	0.040	0.20–0.35	0.20–0.30	4023
4024	0.20–0.25	0.70–0.90	0.040	0.035 0.050	0.20–0.35	0.20–0.30	4024
4027	0.25–0.30	0.70–0.90	0.040	0.040	0.20–0.35	0.20–0.30	4027
4028	0.25–0.30	0.70–0.90	0.040	0.035 0.050	0.20–0.35	0.20–0.30	4028
4032	0.30–0.35	0.70–0.90	0.040	0.040	0.20–0.35	0.20–0.30	4032
4037	0.35–0.40	0.70–0.90	0.040	0.040	0.20–0.35	0.20–0.30	4037
4042	0.40–0.45	0.70–0.90	0.040	0.040	0.20–0.35	0.20–0.30	4042
4047	0.45–0.50	0.70–0.90	0.040	0.040	0.20–0.35	0.20–0.30	4047
4053	0.50–0.56	0.75–1.00	0.040	0.040	0.20–0.35	0.20–0.30	4053
4063	0.60–0.67	0.75–1.00	0.040	0.040	0.20–0.35	0.20–0.30	4063
4068	0.63–0.70	0.75–1.00	0.040	0.040	0.20–0.35	0.20–0.30	0468

TABLE 5—*Chromium-Molybdenum Steels*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %								CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Ni	Cr	Mo	
4119	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	—	0.40–0.60	0.20–0.30	—
4130	0.28–0.33	0.40–0.60	0.040	0.040	0.20–0.35	—	0.80–1.10	0.15–0.25	4130
4137	0.35–0.40	0.70–0.90	0.040	0.040	0.20–0.35	—	0.80–1.10	0.15–0.25	4137
4140	0.38–0.43	0.75–1.00	0.040	0.040	0.20–0.35	—	0.80–1.10	0.15–0.25	4140
4145	0.43–0.48	0.75–1.00	0.040	0.040	0.20–0.35	—	0.80–1.10	0.15–0.25	4145
4150	0.48–0.53	0.75–1.00	0.040	0.040	0.20–0.35	—	0.80–1.10	0.15–0.25	4150

TABLE 6—*Nickel-Chromium-Molybdenum Steels*[a]

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %								CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Ni	Cr	Mo	
4317	0.15–0.20	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	0.40–0.60	0.20–0.30	4317
4320	0.17–0.22	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	0.40–0.60	0.20–0.30	4320
4340	0.38–0.43	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	0.70–0.90	0.20–0.30	4340

[a] See also Table 11.

TABLE 7—*Nickel-Molybdenum Steels*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %								CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Ni	Cr	Mo	
4608	0.06–0.11	0.25–0.45	0.040	0.040	0.25 max	1.40–1.75	—	0.15–0.25	4608
4615	0.13–0.18	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	—	0.20–0.30	4615
4617	0.15–0.20	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	—	0.20–0.30	—
4620	0.17–0.22	0.45–0.65	0.040	0.040	0.20–0.35	1.65–2.00	—	0.20–0.30	4620
X4620	0.18–0.23	0.50–0.70	0.040	0.040	0.20–0.35	1.65–2.00	—	0.20–0.30	—
4621	0.18–0.23	0.70–0.90	0.040	0.040	0.20–0.35	1.65–2.00	—	0.20–0.30	4621
4640	0.38–0.43	0.60–0.80	0.040	0.040	0.20–0.35	1.65–2.00	—	0.20–0.30	4640
4812	0.10–0.15	0.40–0.60	0.040	0.040	0.20–0.35	3.25–3.75	—	0.20–0.30	4812
4815	0.13–0.18	0.40–0.60	0.040	0.040	0.20–0.35	3.25–3.75	—	0.20–0.30	4815
4817	0.15–0.20	0.40–0.60	0.040	0.040	0.20–0.35	3.25–3.75	—	0.20–0.30	4817
4820	0.18–0.23	0.50–0.70	0.040	0.040	0.20–0.35	3.25–3.75	—	0.20–0.30	4820

TABLE 8—*Chromium Steels*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %						CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Cr	
5045	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	0.55–0.75	5045
5046	0.43–0.50	0.75–1.00	0.040	0.040	0.20–0.35	0.20–0.35	5046
5115	0.13–0.18	0.70–0.90	0.040	0.040	0.20–0.35	0.70–0.90	—
5120	0.17–0.22	0.70–0.90	0.040	0.040	0.20–0.35	0.70–0.90	5120
5130	0.28–0.33	0.70–0.90	0.040	0.040	0.20–0.35	0.80–1.10	5130
5132	0.30–0.35	0.60–0.80	0.040	0.040	0.20–0.35	0.75–1.00	5132
5135	0.33–0.38	0.60–0.80	0.040	0.040	0.20–0.35	0.80–1.05	5135
5140	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	0.70–0.90	5140
5145	0.43–0.48	0.70–0.90	0.040	0.040	0.20–0.35	0.70–0.90	5145
5147	0.45–0.52	0.70–0.95	0.040	0.040	0.20–0.35	0.85–1.15	5147
5150	0.48–0.53	0.70–0.90	0.040	0.040	0.20–0.35	0.70–0.90	5150
5152	0.48–0.55	0.70–0.90	0.040	0.040	0.20–0.35	0.90–1.20	5152
5160	0.55–0.65	0.75–1.00	0.040	0.040	0.20–0.35	0.70–0.90	5160
50100[a]	0.95–1.10	0.25–0.45	0.025	0.025	0.20–0.35	0.40–0.60	E50100
51100[a]	0.95–1.10	0.25–0.45	0.025	0.025	0.20–0.35	0.90–1.15	E51100
52100[a]	0.95–1.10	0.25–0.45	0.025	0.025	0.20–0.35	1.30–1.60	E52100

[a] Electric-furnace steel.

TABLE 9—*Chromium-Vanadium Steel*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %							CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Cr	Minimum V	
6150	0.48–0.53	0.70–0.90	0.040	0.040	0.20–0.35	0.80–1.10	0.15	6150

Where the tables show no letter prefix to the AISI number, the steel is predominantly open hearth.

For standard variations in composition limits, refer to Table 4 of the SAE Standard on Permissible Variations from Specified Chemical Ranges and Limits for Steels.

TABLE 10—*Silicon-Manganese Steels*

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %						CORRESPONDING AISI NUMBER
	C	Mn	Maximum P	Maximum S	Si	Cr	
9254	0.50–0.60	0.50–0.80	0.040	0.040	1.20–1.60	0.50–0.80	—
9255	0.50–0.60	0.70–0.95	0.040	0.040	1.80–2.20	—	9255
9260	0.55–0.65	0.70–1.00	0.040	0.040	1.80–2.20	—	9260
9261	0.55–0.65	0.75–1.00	0.040	0.040	1.80–2.20	0.10–0.25	9261
9262	0.55–0.65	0.75–1.00	0.040	0.040	1.80–2.20	0.25–0.40	9262

TABLE 11—*Nickel-Chromium-Molybdenum Steels*[a]

SAE Number	LADLE CHEMICAL COMPOSITION LIMITS, %								CORRESPONDING AISI NUMBER
	C	Mn	P	S	Si	Ni	Cr	Mo	
8615	0.13–0.18	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8615
8617	0.15–0.20	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8617
8620	0.18–0.23	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8620
8622	0.20–0.25	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8622
8625	0.23–0.28	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8625
8627	0.25–0.30	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8627
8630	0.28–0.33	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8630
8632	0.30–0.35	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8632
8635	0.33–0.38	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8635
8637	0.35–0.40	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8637
8640	0.38–0.43	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8640
8641	0.38–0.43	0.75–1.00	0.040	0.040 0.060	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8641
8642	0.40–0.45	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8642
8645	0.43–0.48	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8645
8647	0.45–0.50	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8647
8650	0.48–0.53	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8650
8653	0.50–0.56	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.50–0.80	0.15–0.25	8653
8655	0.50–0.60	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8655
8660	0.55–0.65	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	8660
8719	0.18–0.23	0.60–0.80	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.20–0.30	8719
8720	0.18–0.23	0.70–0.90	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.20–0.30	8720
8735	0.33–0.38	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.20–0.30	8735
8740	0.38–0.43	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.20–0.30	8740
8745	0.43–0.48	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.20–0.30	8745
8750	0.48–0.53	0.75–1.00	0.040	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.20–0.30	8750
9310[b]	0.08–0.13	0.45–0.65	0.025	0.025	0.20–0.35	3.00–3.50	1.00–1.40	0.08–0.15	E9310
9315[b]	0.13–0.18	0.45–0.65	0.025	0.025	0.20–0.35	3.00–3.50	1.00–1.40	0.08–0.15	E9315
9317[b]	0.15–0.20	0.45–0.65	0.025	0.025	0.20–0.35	3.00–3.50	1.00–1.40	0.08–0.15	E9317
9840	0.38–0.43	0.70–0.90	0.040	0.040	0.20–0.35	0.85–1.15	0.70–0.90	0.20–0.30	9840

[a] See also Table 6.
[b] Electric-furnace steel.

Hardenability Bands for H Steels

SAE Standard

Report of Iron and Steel Technical Committee approved August 1947 and last revised April 1950.

[*As the result of cooperative work by the SAE Iron and Steel Technical Committee—Division III and the Technical Committee on Alloy Steel Bars of the American Iron and Steel Institute, hardenability bands have been devised which are considered satisfactory for use in describing certain characteristics of constructional alloy steels. The hardenability limits and their conditions of use as set forth in this Standard were determined by the standard 1-in. end-quench hardenability test.*

Tentative hardenability bands for use with the H steels were previously published as No. 11 of the SAE-AISI Contributions to the Metallurgy of Steel in July 1944 and in a later edition in January 1947. The June 1945 issue of Section 10 of the AISI Steel Products Manual also contained the H steels and corresponding hardenability bands. Since 1945, there have been many improvements in the hardenability bands and some changes in band shape resulting from experience. By joint action, the SAE and AISI committees removed the H steels and corresponding hardenability bands from their tentative status in 1948.

Minimum and maximum hardenability limits for each of the H steels are tabulated in this Standard in Rockwell C hardness. These values are rounded off to the nearest full hardness unit and are to be used for specification purposes. The hardenability bands are shown also in graphical form.

The SAE and AISI committees continue to collect and compile all information on steels furnished to these hardenability limits to determine what further modifications are needed.]

Grades of Steel—H steels and their corresponding minimum and maximum hardenability limits are shown for all of the alloy steels of Tables 3a to 3v of this Standard for which there were sufficient hardenability data and for which grades the standard end-quench test can be used. As information is accumulated on other grades, this publication will be supplemented.

Chemical Composition Limits—In order to afford steel producers the latitude in manufacturing operations necessary to meet a common standard of hardenability limits, the chemical composition limits of these steels have been modified somewhat from the ranges or limits applicable to the same grades when specified by chemical composition only. These modifications permit adjustments in manufacturing ranges of chemistry to correct for individual plant melting characteristics which might otherwise influence the levels and widths of the bands. The modifications have not been great enough to influence the general characteristics of the original compositions of the series under consideration.

The chemical composition limits for both electric-furnace and open-hearth steels are outlined in Table 1 and are subject to the permissible variations for check analysis outlined in Table 2.

These chemical compositions apply only to bars, billets, or blooms which are not more than 200 sq in. in cross-sectional area, nor more than 18 in. in width, and which weigh not more than 10,000 lb per piece.

Identification—As a means of identifying steels specified to hardenability band limits, the suffix letter "H" has been added to the conventional series number. It is quite important that steel consumers use the suffix letter in specification requirements, as there is no other means of determining when hardenability band limits apply. When the suffix letter is used, all the conditions pertaining to chemical composition limits, restrictions, testing technique, and so forth, as outlined herein apply.

Grain Size—The limits set forth for bands are intended to apply to steels manufactured to fine-grain steel practice. In cases where coarse-grain steel is desired, the hardenability limits shall be a matter of agreement between producer and consumer.

Use of Hardenability Limits—Band limits are shown graphically with Tables 3a to 3v. They are so depicted for convenience in estimating the hardness values obtainable at various locations on the end-quench test bar and for quick comparisons of the various H grades. The graphs are not to be used for specification purposes.

Tables 3a to 3v, inclusive, show the minimum and maximum hardness values (Rockwell C) at the corresponding distances from the quenched end of the standard end-quench test bar for all the H steels. Values from these tables are to be used for specification purposes and it is recommended that two points be used to designate the hardenability. Those two points may be designated in any one of the following ways:

1. The minimum and maximum hardness values at any desired distance. This method is illustrated on Fig. 1 as points A-A and would be specified as "J39-52 equals 4 sixteenths." Obviously the distance selected would be that distance on the end-quench test bar which corresponds to the section used by the consumer.

2. The minimum and maximum distances at which any desired hardness value occurs. This method is illustrated on Fig. 1 as points B-B and would be specified as "J42 equals 3 to 8 sixteenths."

3. Two maximum hardness values at two desired distances, illustrated on Fig. 1 as points C-C.

4. Two minimum hardness values at two desired distances, illustrated on Fig. 1 as D-D.

5. Any minimum hardness plus any maximum hardness.

Methods of indicating hardenability designation are:

1. Minimum and maximum hardness values at a desired distance, Example A-A: J39/52 = 4/16 in.

2. A desired hardness value at minimum and maximum distances, Example B-B: J42 = 3/16 to 8/16 in. (Minimum distance to nearest sixteenth of an inch at left and maximum to nearest sixteenth of an inch at right.)

3. Two maximum hardness values at two desired distances, Example C-C: J50 = 5/16 in. (max), J34 = 12/16 in. (max).

4. Two minimum hardness values at two desired distances, Example D-D: J35 = 5/16 in. (min), J21 = 16/16 in. (min).

General—The steel producer will show on the proper shipping papers or by some other acceptable means the hardenability characteristics of the heat involved when an H steel is specified. The heat hardenability will be shown either by hardness values at specified reference points or by hardness values at the following distances from the quenched end of the test specimen: 1/16, 1/8, 1/4, 1/2, 3/4, 1, 1 1/4, 1 1/2, 1 3/4, and 2 in. No reading below 20 Rockwell C will be reported. The heat hardenability will be determined from either a cast or a forged end-quench harden-

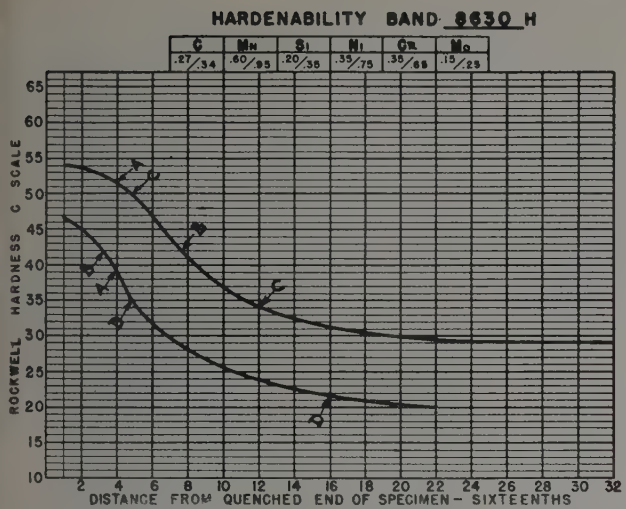


FIG. 1.—SAMPLE GRAPH ILLUSTRATING METHODS OF SPECIFYING REQUIREMENTS. (TABULATED VALUES MUST BE USED IN ORDERING)

In cases where it is considered desirable, the maximum and minimum limits at the 1/16-in. point may be specified in addition to the other two points.

In cases where it is necessary to specify more than two points on the hardenability band (exclusive of the maximum and minimum limits at 1/16 in.) a tolerance of two points Rockwell C over any small portion of either curve (except at 1/16 in.) is to be permitted. This is necessary because it will be found that curves of individual heats may vary somewhat in shape from the standard band limits, and thus may deviate slightly at one or two positions if the full-length curves are specified. The hardenability specification should be based upon one of the following, but not both:

1. Two specific points on the hardenability band (plus 1/16-in. limits if desired), in which case the tolerance described above does not apply.

2. More than two specific points up to the entire hardenability band, in which case the tolerance described above does apply. Method 1 is usually preferred as more pertinent.

ability test bar.

The technique of testing for acceptance should be in accordance with the SAE Recommended Practice, "Method of Determining Hardenability."

The hardenability limits set forth have been formulated to conform with steel manufacturing practices which represent at this time, the narrowest limits that can be produced with regular quality steel. Those limits may be used in conjunction with higher quality classifications when desired. In either case, all conditions and quality features outlined in Section 10 of the latest AISI Steel Products Manual apply except for the conditions concerning chemical compositions, size, and shape of products which are modified herein.

TABLE 1[a]—*Chemical Composition Ranges for Electric-Furnace or Open-Hearth Steel Bars, Billets, and Blooms*

Steel Number (SAE or AISI)	CHEMICAL COMPOSITION,[b, c] %					
	C	Mn	Si	Ni	Cr	Mo
1320 H	0.17–0.24	1.50–2.00	0.20–0.35	—	—	—
1330 H	0.27–0.34	1.50–2.00	0.20–0.35	—	—	—
1335 H	0.32–0.39	1.50–2.00	0.20–0.35	—	—	—
1340 H	0.37–0.45	1.50–2.00	0.20–0.35	—	—	—
2330 H	0.27–0.34	0.55–0.85	0.20–0.35	3.20–3.80	—	—
2512 H	0.08–0.15	0.35–0.65	0.20–0.35	4.70–5.30	—	—
2515 H	0.11–0.18	0.35–0.65	0.20–0.35	4.70–5.30	—	—
2517 H	0.14–0.21	0.35–0.65	0.20–0.35	4.70–5.30	—	—
3120 H	0.17–0.24	0.55–0.85	0.20–0.35	1.00–1.50	0.50–0.80	—
3130 H	0.27–0.34	0.55–0.85	0.20–0.35	1.00–1.50	0.50–0.80	—
3135 H	0.32–0.39	0.55–0.85	0.20–0.35	1.00–1.50	0.50–0.80	—
3140 H	0.37–0.45	0.60–0.95	0.20–0.35	1.00–1.50	0.50–0.80	—
3310 H	0.07–0.14	0.35–0.65	0.20–0.35	3.20–3.80	1.35–1.75	—
3316 H	0.13–0.20	0.35–0.65	0.20–0.35	3.20–3.80	1.35–1.75	—
4032 H	0.30–0.37	0.60–0.95	0.20–0.35	—	—	0.20–0.30
4037 H	0.35–0.43	0.60–0.95	0.20–0.35	—	—	0.20–0.30
4042 H	0.40–0.48	0.60–0.95	0.20–0.35	—	—	0.20–0.30
4047 H	0.44–0.52	0.60–0.95	0.20–0.35	—	—	0.20–0.30
4053 H	0.49–0.57	0.70–1.05	0.20–0.35	—	—	0.20–0.30
4063 H	0.59–0.69	0.70–1.05	0.20–0.35	—	—	0.20–0.30
4068 H	0.62–0.72	0.70–1.05	0.20–0.35	—	—	0.20–0.30

(*Table continued on next page.*)

TABLE 1[a]—*Chemical Composition Ranges for Electric-Furnace or Open-Hearth Steel Bars, Billets, and Blooms (Continued)*

Steel Number (SAE or AISI)	CHEMICAL COMPOSITION,[b,c] %					
	C	Mn	Si	Ni	Cr	Mo
4130 H	0.27–0.34	0.35–0.65	0.20–0.35	—	0.80–1.15	0.15–0.25
4132 H	0.30–0.37	0.35–0.65	0.20–0.35	—	0.80–1.15	0.15–0.25
4135 H	0.32–0.39	0.60–0.95	0.20–0.35	—	0.80–1.15	0.15–0.25
4137 H	0.35–0.43	0.60–0.95	0.20–0.35	—	0.80–1.15	0.15–0.25
4140 H	0.37–0.45	0.70–1.05	0.20–0.35	—	0.80–1.15	0.15–0.25
4142 H	0.40–0.48	0.70–1.05	0.20–0.35	—	0.80–1.15	0.15–0.25
4145 H	0.42–0.50	0.70–1.05	0.20–0.35	—	0.80–1.15	0.15–0.25
4147 H	0.44–0.52	0.70–1.05	0.20–0.35	—	0.80–1.15	0.15–0.25
4150 H	0.46–0.54	0.70–1.05	0.20–0.35	—	0.80–1.15	0.15–0.25
4317 H	0.14–0.21	0.40–0.70	0.20–0.35	1.50–2.00	0.35–0.65	0.20–0.30
4320 H	0.16–0.23	0.40–0.70	0.20–0.35	1.50–2.00	0.35–0.65	0.20–0.30
4337 H	0.35–0.43	0.55–0.85	0.20–0.35	1.50–2.00	0.65–0.95	0.20–0.30
4340 H	0.37–0.45	0.60–0.95	0.20–0.35	1.50–2.00	0.65–0.95	0.20–0.30
4620 H	0.17–0.24	0.40–0.70	0.20–0.35	1.50–2.00	—	0.20–0.30
X4620 H	0.17–0.24	0.45–0.75	0.20–0.35	1.50–2.00	—	0.20–0.30
4621 H	0.17–0.24	0.60–0.95	0.20–0.35	1.50–2.00	—	0.20–0.30
4640 H	0.37–0.45	0.55–0.85	0.20–0.35	1.50–2.00	—	0.20–0.30
4812 H	0.10–0.17	0.30–0.60	0.20–0.35	3.20–3.80	—	0.20–0.30
4815 H	0.12–0.19	0.35–0.65	0.20–0.35	3.20–3.80	—	0.20–0.30
4817 H	0.14–0.21	0.35–0.65	0.20–0.35	3.20–3.80	—	0.20–0.30
4820 H	0.17–0.24	0.45–0.75	0.20–0.35	3.20–3.80	—	0.20–0.30
5120 H	0.17–0.24	0.60–0.95	0.20–0.35	—	0.65–0.95	—
5130 H	0.27–0.34	0.60–0.95	0.20–0.35	—	0.80–1.15	—
5132 H	0.28–0.35	0.50–0.85	0.20–0.35	—	0.70–1.05	—
5135 H	0.32–0.39	0.55–0.85	0.20–0.35	—	0.75–1.10	—
5140 H	0.37–0.45	0.60–0.95	0.20–0.35	—	0.65–0.95	—
5145 H	0.42–0.50	0.60–0.95	0.20–0.35	—	0.65–0.95	—
5147 H	0.44–0.52	0.65–1.00	0.20–0.35	—	0.85–1.20	—
5150 H	0.46–0.54	0.60–0.95	0.20–0.35	—	0.65–0.95	—
5152 H	0.48–0.56	0.60–0.95	0.20–0.35	—	0.90–1.25	—
5160 H	0.55–0.65	0.70–1.05	0.20–0.35	—	0.65–0.95	—
6150 H	0.46–0.54	0.60–0.95	0.20–0.35	—	0.80–1.15	(0.15 min V[e])
8617 H	0.14–0.21	0.60–0.95	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8620 H	0.17–0.24	0.60–0.95	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8622 H	0.20–0.27	0.60–0.95	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8625 H	0.22–0.29	0.60–0.95	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8627 H	0.25–0.32	0.60–0.95	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8630 H	0.27–0.34	0.60–0.95	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8632 H	0.30–0.37	0.60–0.95	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8635 H	0.32–0.39	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8637 H	0.35–0.43	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8640 H	0.37–0.45	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8641 H[d]	0.37–0.45	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8642 H	0.40–0.48	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8645 H	0.42–0.50	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8647 H	0.44–0.52	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8650 H	0.46–0.54	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8653 H	0.49–0.57	0.70–1.05	0.20–0.35	0.35–0.75	0.50–0.85	0.15–0.25
8655 H	0.50–0.60	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25
8660 H	0.55–0.65	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.15–0.25

(*Table continued on next page.*)

TABLE 1[a]—*Chemical Composition Ranges for Electric-Furnace or Open-Hearth Steel Bars, Billets, and Blooms (Concluded)*

Steel Number (SAE or AISI)	CHEMICAL COMPOSITION,[b, c] %					
	C	Mn	Si	Ni	Cr	Mo
8720 H	0.17–0.24	0.60–0.95	0.20–0.35	0.35–0.75	0.35–0.65	0.20–0.30
8735 H	0.32–0.39	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.20–0.30
8740 H	0.37–0.45	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.20–0.30
8742 H	0.40–0.48	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.20–0.30
8745 H	0.42–0.50	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.20–0.30
8747 H	0.44–0.52	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.20–0.30
8750 H	0.46–0.54	0.70–1.05	0.20–0.35	0.35–0.75	0.35–0.65	0.20–0.30
9260 H	0.55–0.65	0.70–1.05	1.70–2.20	—	—	—
9261 H	0.55–0.65	0.70–1.05	1.70–2.20	—	0.05–0.35	—
9262 H	0.55–0.65	0.70–1.05	1.70–2.20	—	0.20–0.50	—
9310 H	0.07–0.14	0.40–0.70	0.20–0.35	2.95–3.55	1.00–1.45	0.08–0.15
9437 H	0.35–0.43	0.85–1.25	0.20–0.35	0.25–0.65	0.25–0.55	0.08–0.15
9440 H	0.37–0.45	0.85–1.25	0.20–0.35	0.25–0.65	0.25–0.55	0.08–0.15
9442 H	0.40–0.48	0.95–1.35	0.20–0.35	0.25–0.65	0.25–0.55	0.08–0.15
9445 H	0.42–0.50	0.95–1.35	0.20–0.35	0.25–0.65	0.25–0.55	0.08–0.15

[a] The ranges and limits in this table apply only to material not exceeding 200 sq in. in cross-sectional area, 18 in. in width, or 10,000 lb per piece in weight. Ranges and limits are subject to the standard permissible variations for check analysis shown in Table 2 of this Standard.
[b] Small quantities of certain elements may be found in alloy steel which are not specified or required. These elements are to be considered as incidental and acceptable to the following maximum amounts: copper to 0.35%, nickel to 0.25%, chromium to 0.20%, and molybdenum to 0.06%.
[c] Maximum phosphorus and sulfur in open-hearth steel are to be 0.040% each, except for 8641 H. Maximum phosphorus and sulfur are to be 0.025% each, except for 8641 H.
[d] Sulfur content range is 0.040–0.060%.
[e] V = vanadium.

TABLE 2—*Standard Permissible Variations from Specified Chemical Ranges and Limits Applicable to Electric-Furnace and Open-Hearth H Steels*

ELEMENT	LIMIT OR MAXIMUM OF SPECIFIED RANGE, %	STANDARD VARIATION BY SIZE RANGES, % OVER MAXIMUM LIMIT OR UNDER MINIMUM LIMIT	
		100 sq in. or less	Over 100 to 200 sq. in.
Carbon	to 0.25 inclusive	0.01	0.02
	over 0.25 to 0.75 inclusive	0.02	0.03
Manganese	to 0.90 inclusive	0.03	0.04
	over 0.90 to 2.10	0.04	0.05
Phosphorus	over maximum only	0.005	0.01
Sulfur	to 0.60 inclusive	0.005	0.01
Silicon	to 0.35 inclusive	0.02	0.02
	over 0.35 to 2.20 inclusive	0.05	0.06
Nickel	to 1.00 inclusive	0.03	0.03
	over 1.00 to 2.00 inclusive	0.05	0.05
	over 2.00 to 5.30 inclusive	0.07	0.07
Chromium	to 0.90 inclusive	0.03	0.04
	over 0.90 to 2.10 inclusive	0.05	0.06
Molybdenum	to 0.20 inclusive	0.01	0.01
	over 0.20 to 0.40 inclusive	0.02	0.03
Vanadium	Minimum value only specified; check under specifications	0.01	0.01

(*Continued on next page.*)

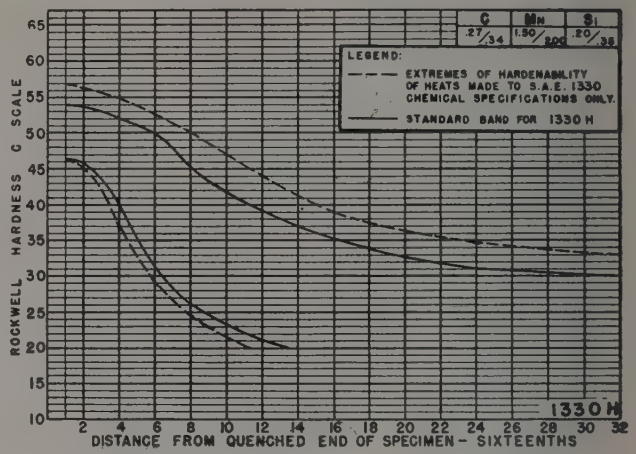
1320 H, 1330 H, 1335 H, 1340 H

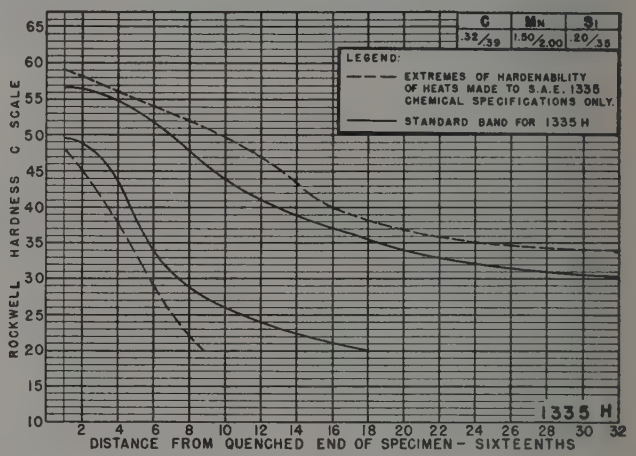
TABLE 3a—*Band Limits for 1320 H, 1330 H, 1335 H, and 1340 H*

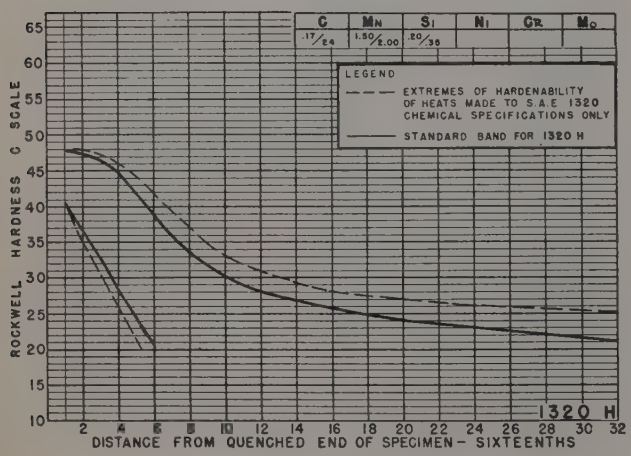
J DISTANCE, IN.	GRADE							
	1320 H		1330 H		1335 H		1340 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	48	40	54	46	57	49	60	52
1/8	47	37	54	46	57	49	60	52
3/16	46	32	53	43	56	47	59	51
1/4	45	28	52	40	55	44	58	49
5/16	42	23	51	35	54	38	57	46
3/8	39	21	50	31	52	34	56	40
7/16	36	—	48	28	50	31	55	35
1/2	33	—	45	26	48	29	54	33
9/16	32	—	43	25	46	27	52	31
5/8	30	—	42	23	44	26	51	29
11/16	29	—	40	22	42	25	50	28
3/4	28	—	39	21	41	24	48	27
13/16	28	—	38	20	40	23	46	26
7/8	27	—	37	—	39	22	44	25
15/16	26	—	36	—	38	22	42	25
1	26	—	35	—	37	21	41	24
1 1/8	25	—	34	—	35	20	39	23
1 1/4	24	—	33	—	34	—	38	23
1 3/8	23	—	32	—	33	—	37	22
1 1/2	23	—	31	—	32	—	36	22
1 5/8	22	—	31	—	31	—	35	21
1 3/4	22	—	31	—	31	—	35	21
1 7/8	22	—	30	—	30	—	34	20
2	21	—	30	—	30	—	34	20

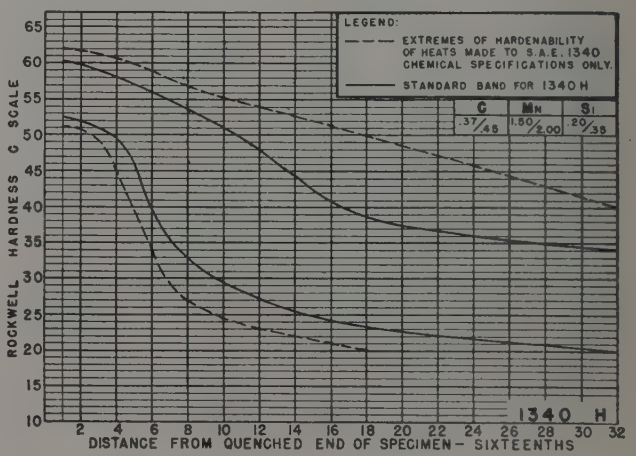
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.


C .27/.34
Mn 1.50/2.00
Si .20/.35
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 1330 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 1330 H
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
1330 H


C .32/.39
Mn 1.50/2.00
Si .20/.35
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 1335 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 1335 H
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
1335 H




LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 1340 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 1340 H
C .37/.45
Mn 1.50/2.00
Si .20/.35
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
1340 H

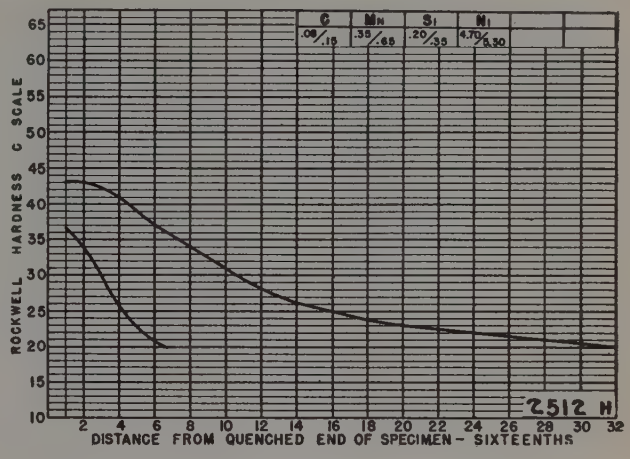
2330 H, 2512 H, 2515 H, 2517 H

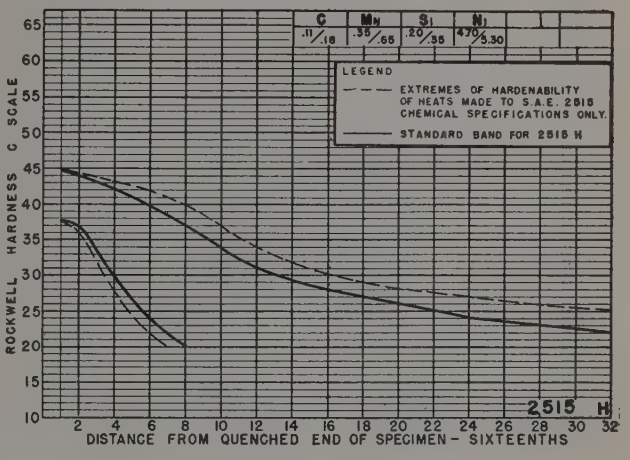
TABLE 3b—*Band Limits for 2330 H, 2512 H, 2515 H, and 2517 H*

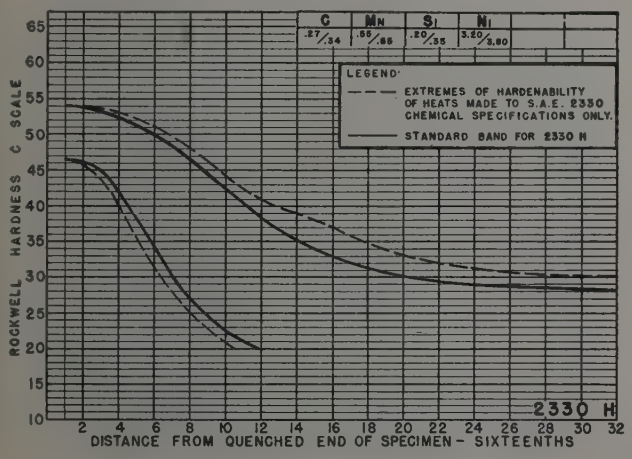
J DISTANCE, IN.	GRADE							
	2330 H		2512 H		2515 H		2517 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	54	46	43	36	45	37	46	39
1/8	54	46	43	34	44	37	46	38
3/16	53	45	42	30	43	33	46	35
1/4	52	42	41	26	42	30	45	31
5/16	51	38	39	23	41	27	44	28
3/8	50	34	37	21	40	24	43	25
7/16	48	30	36	—	38	22	42	23
1/2	46	27	34	—	37	20	41	21
9/16	44	24	32	—	35	—	39	20
5/8	42	22	31	—	34	—	37	—
11/16	40	21	29	—	32	—	35	—
3/4	38	20	28	—	31	—	34	—
13/16	37	—	27	—	30	—	33	—
7/8	35	—	26	—	29	—	32	—
15/16	34	—	25	—	29	—	32	—
1	33	—	25	—	28	—	31	—
1 1/8	31	—	24	—	27	—	30	—
1 1/4	30	—	23	—	26	—	29	—
1 3/8	29	—	23	—	25	—	28	—
1 1/2	29	—	22	—	24	—	27	—
1 5/8	29	—	22	—	24	—	27	—
1 3/4	29	—	21	—	23	—	26	—
1 7/8	28	—	21	—	23	—	26	—
2	28	—	20	—	22	—	25	—

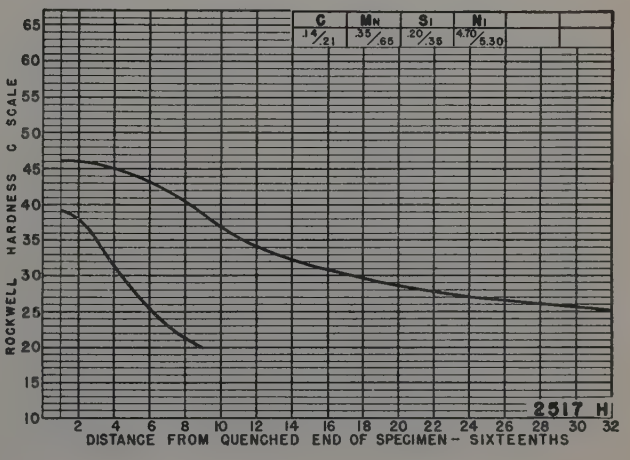
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.




C .11/.18
Mn .35/.65
Si .20/.35
Ni 4.70/5.30
LEGEND
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 2515 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 2515 H
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
2515 H


C .27/.34
Mn .55/.85
Si .20/.35
Ni 3.20/3.80
LEGEND
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 2330 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 2330 H
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
2330 H



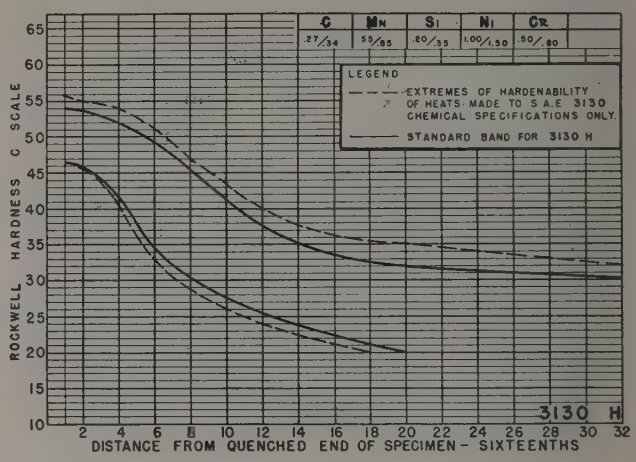
3120 H, 3130 H, 3135 H, 3140 H

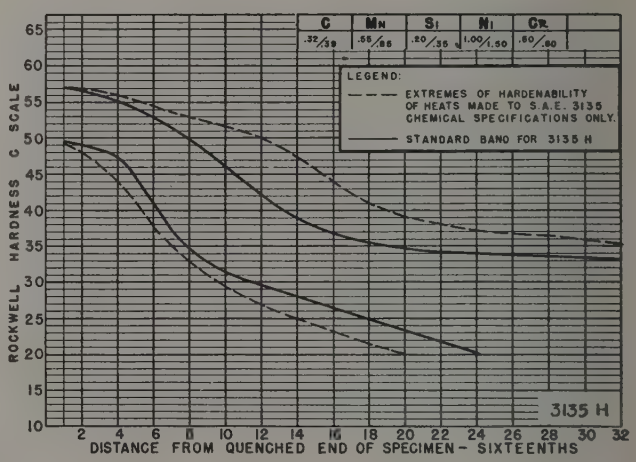
TABLE 3c—*Band Limits for 3120 H, 3130 H, 3135 H, and 3140 H*

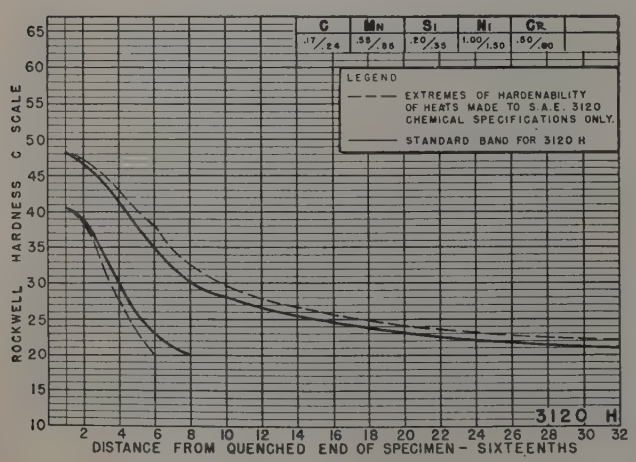
J DISTANCE, IN.	GRADE							
	3120 H		3130 H		3135 H		3140 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	48	40	54	46	57	49	60	52
1/8	47	39	54	46	57	49	60	51
3/16	44	34	53	44	56	48	59	50
1/4	42	30	52	42	55	47	59	49
5/16	38	25	51	38	54	44	58	47
3/8	35	23	49	34	53	41	57	45
7/16	32	21	48	32	51	37	57	43
1/2	30	20	45	30	50	35	56	41
9/16	29	—	43	29	48	33	55	38
5/8	28	—	41	28	46	31	54	36
11/16	27	—	39	26	44	30	53	34
3/4	27	—	38	25	42	29	52	33
13/16	26	—	36	25	40	29	51	32
7/8	26	—	35	24	39	28	50	31
15/16	25	—	34	23	38	27	49	30
1	25	—	34	22	37	26	48	30
1 1/8	24	—	33	21	36	25	46	29
1 1/4	23	—	32	20	35	23	44	28
1 3/8	23	—	32	—	34	22	43	28
1 1/2	22	—	31	—	34	20	42	27
1 5/8	22	—	31	—	34	—	41	27
1 3/4	21	—	31	—	34	—	40	26
1 7/8	21	—	30	—	33	—	40	26
2	21	—	30	—	33	—	39	25

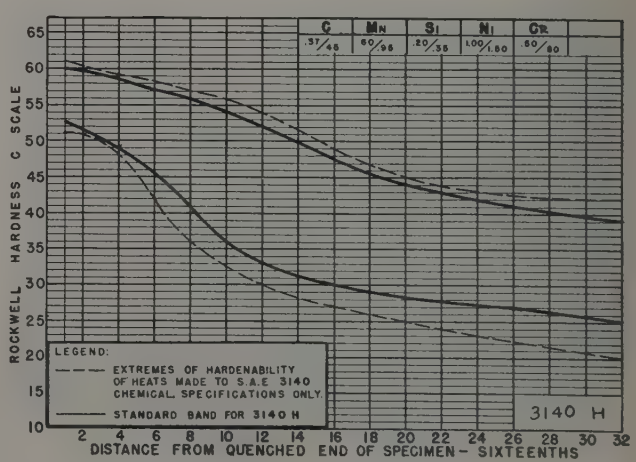
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









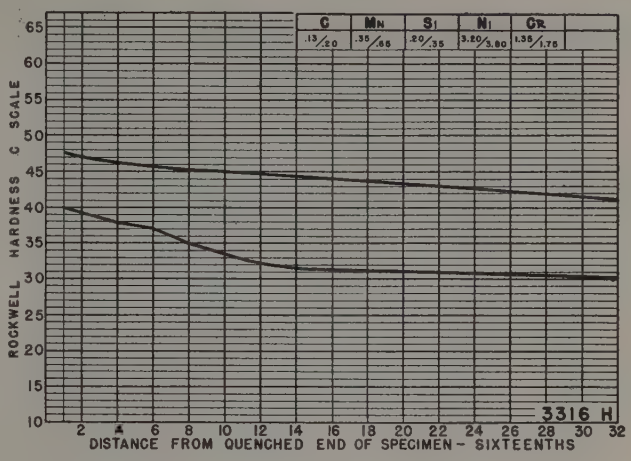
3310 H, 3316 H, 4032 H, 4037 H

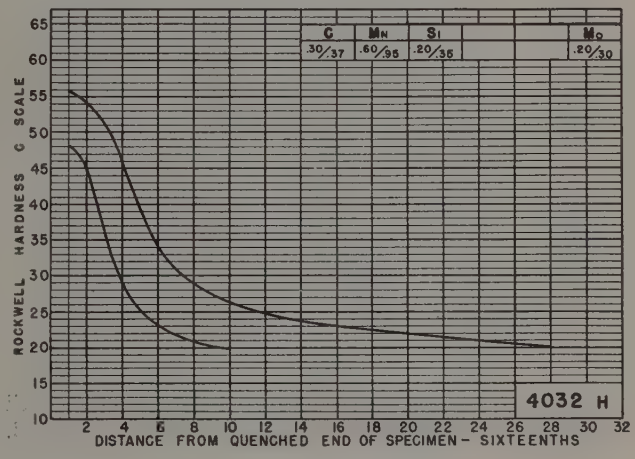
TABLE 3d—*Band Limits for 3310 H, 3316 H, 4032 H, and 4037 H*

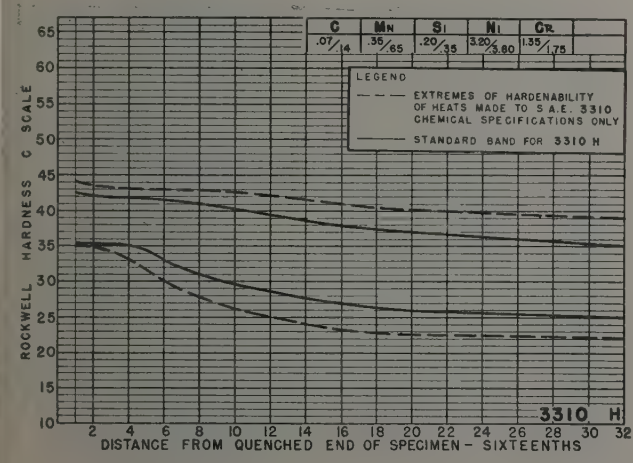
J DISTANCE, IN.	GRADE							
	3310 H		3316 H		4032 H		4037 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	43	35	48	40	56	48	59	51
1/8	42	35	47	39	54	45	57	49
3/16	42	35	47	38	51	36	54	42
1/4	42	35	46	38	46	29	51	35
5/16	42	34	46	37	39	25	45	30
3/8	42	33	46	37	34	23	38	26
7/16	41	32	45	36	31	22	34	23
1/2	41	31	45	35	29	21	32	22
9/16	41	30	45	34	28	20	30	21
5/8	40	30	45	33	26	—	29	20
11/16	40	29	45	33	26	—	28	—
3/4	40	29	45	32	25	—	27	—
13/16	39	28	45	32	24	—	26	—
7/8	39	28	44	32	24	—	26	—
15/16	38	27	44	31	23	—	26	—
1	38	27	44	31	23	—	25	—
1 1/8	37	26	44	31	23	—	25	—
1 1/4	37	26	43	31	22	—	25	—
1 3/8	37	26	43	31	22	—	25	—
1 1/2	36	26	43	31	21	—	24	—
1 5/8	36	25	42	31	21	—	24	—
1 3/4	36	25	42	30	20	—	24	—
1 7/8	35	25	42	30	—	—	23	—
2	35	25	41	30	—	—	23	—

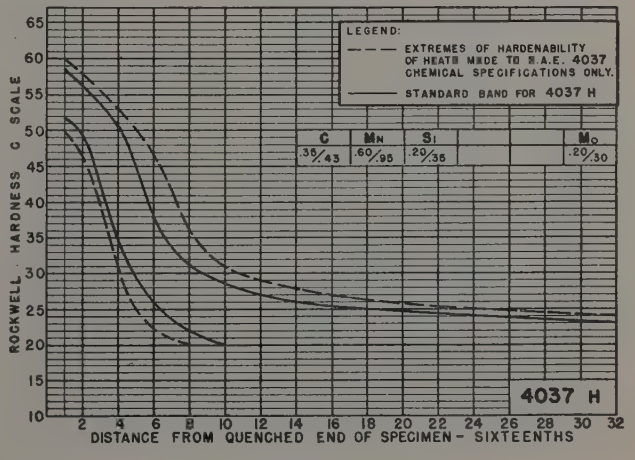
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.








LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 4037 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 4037 H
C .35/.43
Mn .60/.95
Si .20/.35
Mo .20/.30
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN – SIXTEENTHS
4037 H

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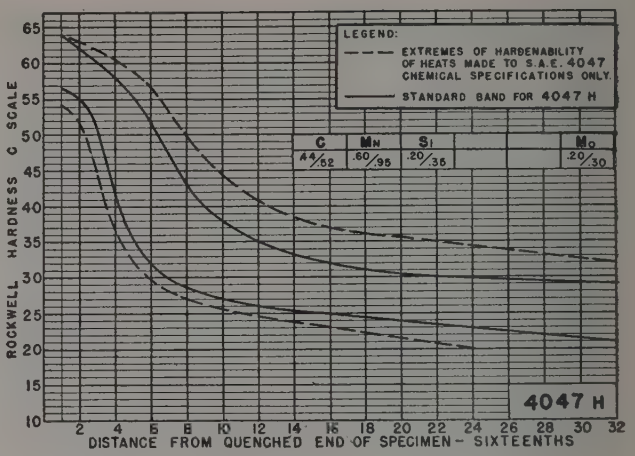
4042 H, 4047 H, 4053 H, 4063 H

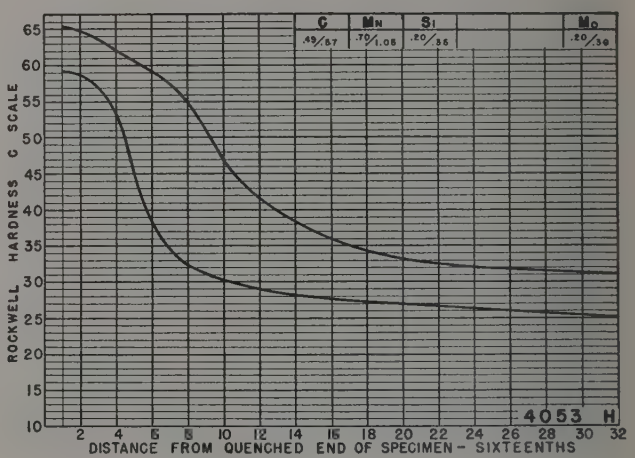
TABLE 3e—*Band Limits for 4042 H, 4047 H, 4053 H, and 4063 H*

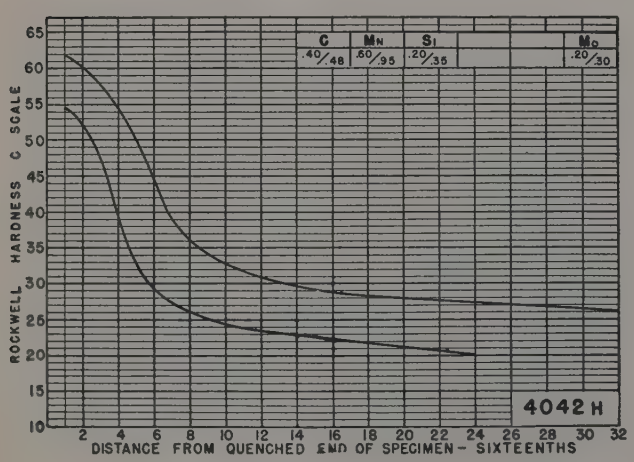
J DISTANCE, IN.	GRADE							
	4042 H		4047 H		4053 H		4063 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	62	54	64	56	65	59	—	60
1/8	60	52	62	55	65	59	—	60
3/16	58	48	60	50	64	57	65	58
1/4	55	40	58	42	62	53	65	56
5/16	50	33	55	35	61	45	65	50
3/8	45	29	52	32	59	38	64	39
7/16	39	27	47	30	57	34	62	36
1/2	36	26	43	28	55	32	61	35
9/16	34	25	40	28	51	31	59	34
5/8	33	24	38	27	47	30	57	33
11/16	32	24	37	26	44	29	54	32
3/4	31	23	35	26	42	29	51	32
13/16	30	23	34	25	40	28	48	32
7/8	30	23	33	25	38	28	46	31
15/16	29	22	33	25	37	28	44	31
1	29	22	32	25	36	28	43	31
1 1/8	28	22	31	24	34	27	41	30
1 1/4	28	21	30	24	33	27	40	30
1 3/8	28	20	30	23	33	27	39	29
1 1/2	27	20	30	23	32	26	38	29
1 5/8	27	—	30	22	32	26	38	28
1 3/4	27	—	29	22	32	26	37	28
1 7/8	26	—	29	21	31	25	37	27
2	26	—	29	21	31	25	36	27

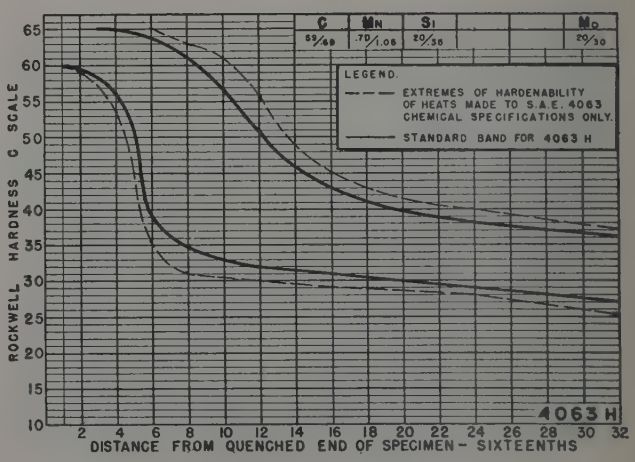
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.


LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 4047 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 4047 H
C .44/.62
Mn .60/.95
Si .20/.35
Mo .20/.30
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
4047 H






C .58/.69
Mn .70/1.05
Si .20/.35
Mo .20/.30
LEGEND.
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 4063 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 4063 H
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
4063 H

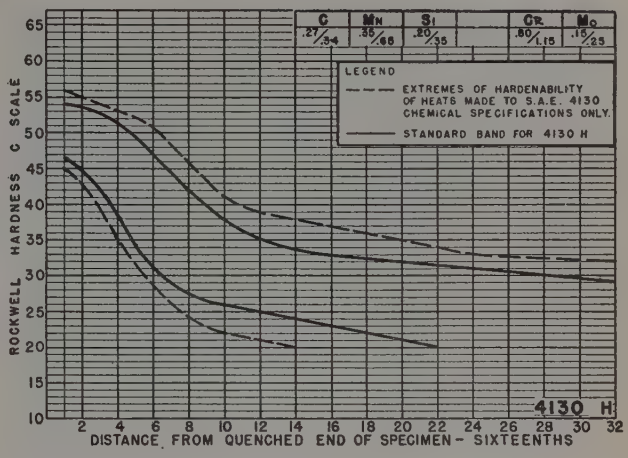
4068 H, 4130 H, 4132 H, 4135 H

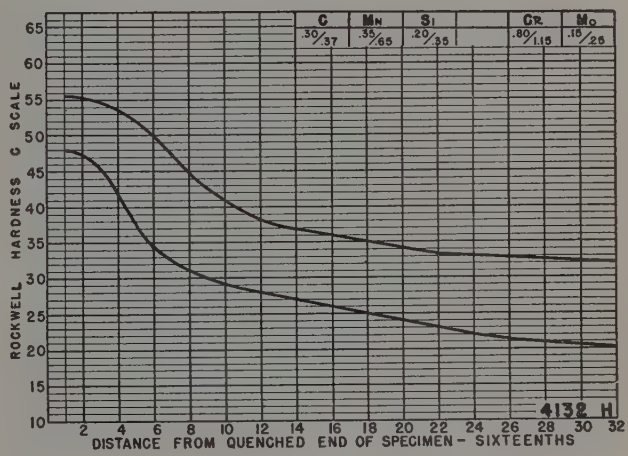
TABLE 3f—*Band Limits for 4068 H, 4130 H, 4132 H, and 4135 H*

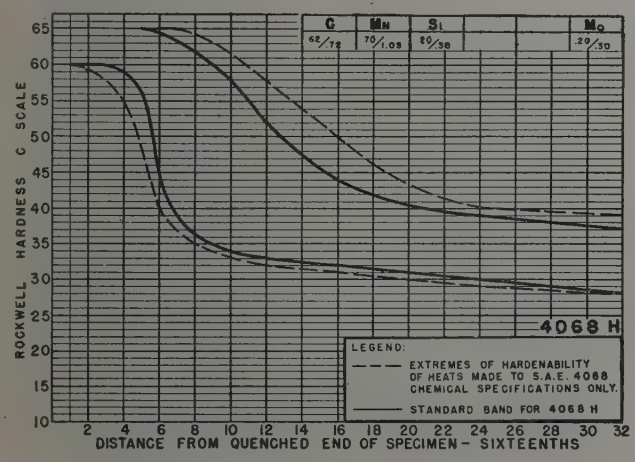
J DISTANCE, IN.	GRADE							
	4068 H		4130 H		4132 H		4135 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	—	60	54	46	56	48	57	50
1/8	—	60	54	45	55	47	57	50
3/16	—	60	53	42	55	45	57	49
1/4	—	59	51	38	54	42	56	48
5/16	65	56	49	34	52	37	56	47
3/8	64	45	47	31	50	34	55	45
7/16	63	39	44	29	47	32	54	42
1/2	62	36	42	27	45	31	53	40
9/16	60	35	40	26	43	30	52	38
5/8	58	34	38	26	41	29	51	36
11/16	55	33	36	25	39	28	50	34
3/4	52	33	35	25	38	28	49	33
13/16	49	33	34	24	37	27	48	32
7/8	47	32	34	24	37	27	47	31
15/16	45	32	33	23	36	26	46	30
1	44	32	33	23	36	26	45	30
1 1/8	42	31	32	22	35	25	44	29
1 1/4	41	31	32	21	34	24	42	28
1 3/8	40	30	32	20	33	23	41	27
1 1/2	39	30	31	—	33	22	40	27
1 5/8	38	29	31	—	33	21	39	27
1 3/4	38	29	30	—	32	21	38	26
1 7/8	38	28	30	—	32	20	38	26
2	37	28	29	—	32	20	37	26

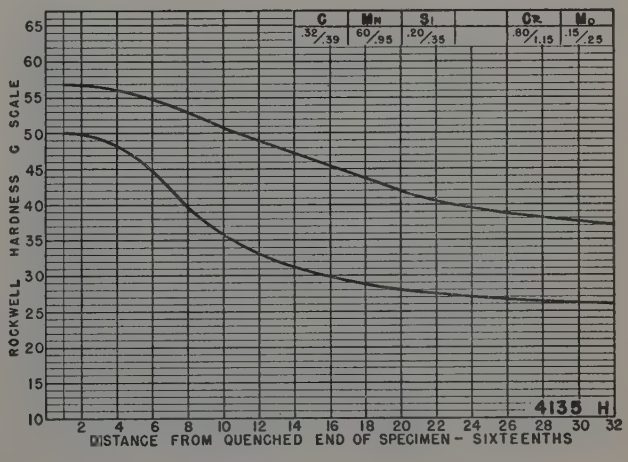
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.






C .62/.72
Mn .70/1.05
Si .20/.35
Mo .20/.30
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 4068 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 4068 H
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
4068 H



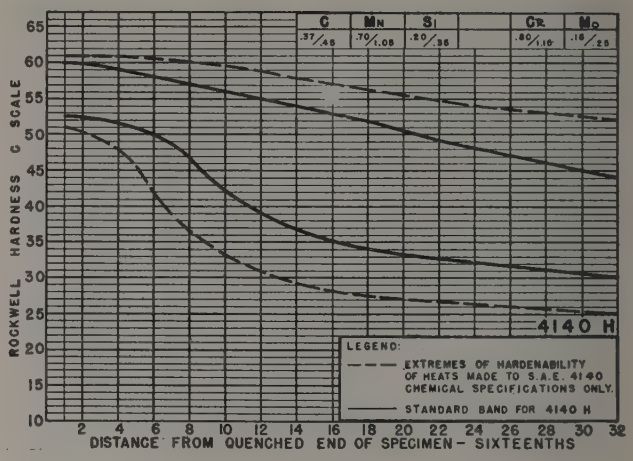
4137 H, 4140 H, 4142 H, 4145 H

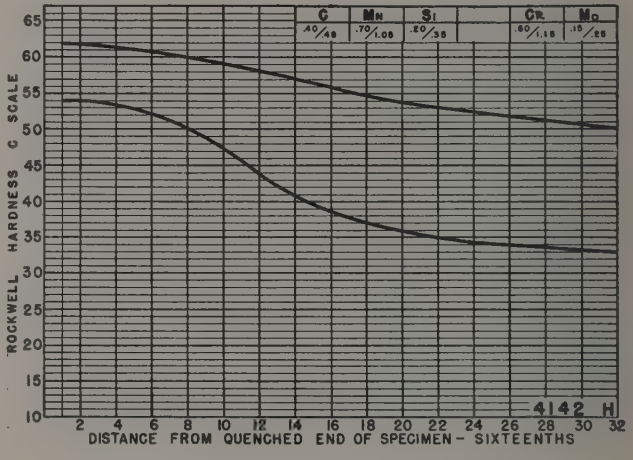
TABLE 3g—*Band Limits for 4137 H, 4140 H, 4142 H, and 4145 H*

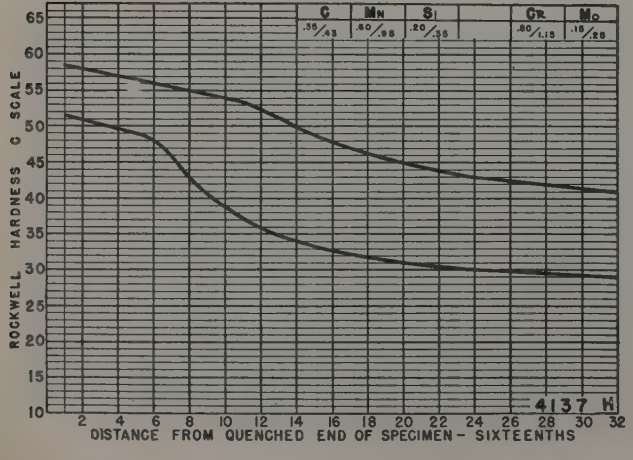
J DISTANCE, IN.	GRADE							
	4137 H		4140 H		4142 H		4145 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	60	51	60	52	62	54	63	55
1/8	58	51	60	52	62	54	63	55
3/16	58	50	60	52	62	54	62	54
1/4	57	49	59	51	61	53	62	54
5/16	57	49	59	51	61	53	62	53
3/8	56	48	58	50	61	52	61	53
7/16	55	45	58	48	60	51	61	52
1/2	55	43	57	47	60	50	61	52
9/16	55	40	57	44	60	49	60	51
5/8	54	39	56	42	59	47	60	50
11/16	53	37	56	40	59	46	60	49
3/4	52	36	55	39	58	44	59	48
13/16	51	35	55	38	58	42	59	46
7/8	50	34	54	37	57	41	59	45
15/16	49	33	54	36	57	40	58	43
1	48	33	53	35	56	39	58	42
1 1/8	46	32	52	34	55	37	57	40
1 1/4	45	31	51	33	54	36	57	38
1 3/8	44	30	49	33	53	35	56	37
1 1/2	43	30	48	32	53	34	55	36
1 5/8	42	30	47	32	52	34	55	35
1 3/4	42	29	46	31	51	34	55	35
1 7/8	41	29	45	31	51	33	55	34
2	41	29	44	30	50	33	54	34

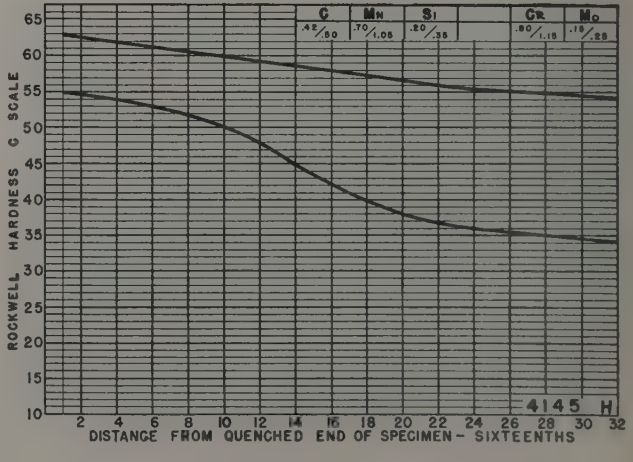
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









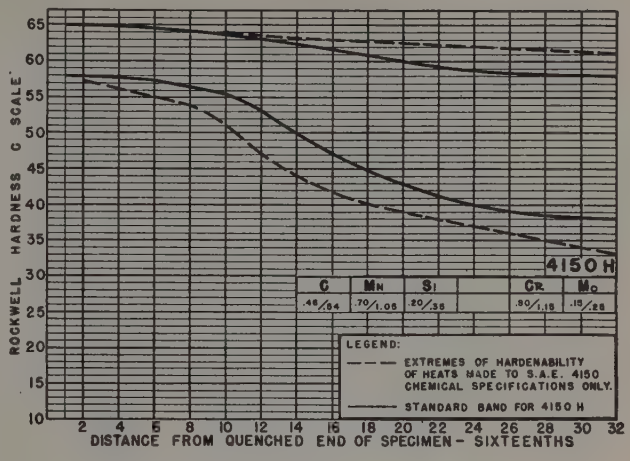
4147 H, 4150 H, 4317 H, 4320 H

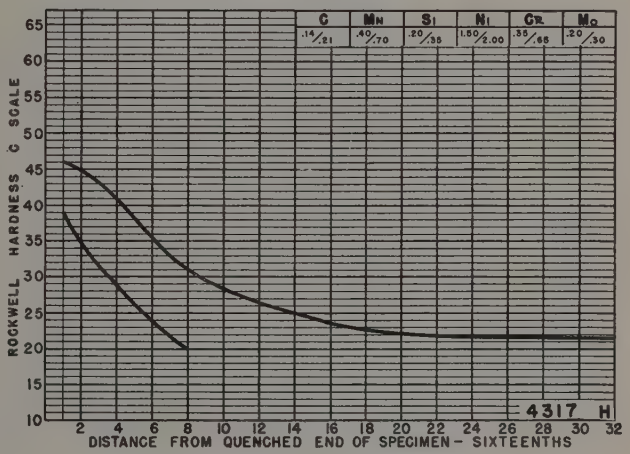
TABLE 3h—*Band Limits for 4147 H, 4150 H, 4317 H, and 4320 H*

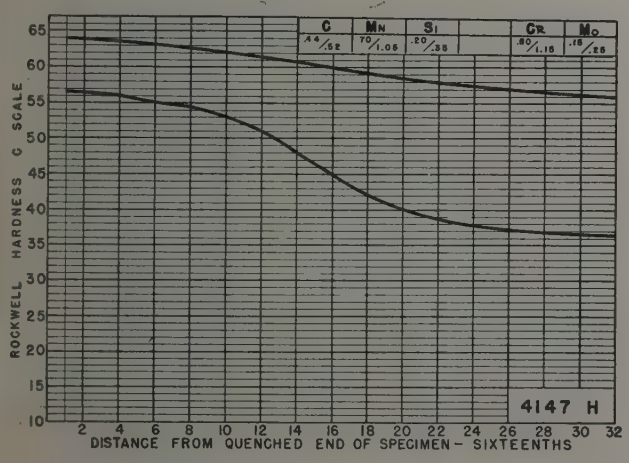
J DISTANCE, IN.	GRADE							
	4147 H		4150 H		4317 H		4320 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	64	56	65	58	46	39	48	40
1/8	64	56	65	58	45	35	47	38
3/16	64	56	65	58	43	31	45	35
1/4	64	56	65	58	41	29	43	32
5/16	63	55	65	58	38	26	41	29
3/8	63	55	65	57	36	24	38	27
7/16	63	55	65	57	33	21	36	25
1/2	63	54	64	56	31	20	34	23
9/16	63	54	64	56	29	—	33	22
5/8	62	53	64	55	28		31	21
11/16	62	52	64	54	27	—	30	20
3/4	62	51	63	53	26	—	29	20
13/16	61	49	63	51	26	—	28	—
7/8	61	48	62	50	25	—	27	—
15/16	60	46	62	48	24	—	27	—
1	60	45	62	47	24	—	26	—
1 1/8	59	42	61	45	23	—	25	—
1 1/4	59	40	60	43	22	—	25	—
1 3/8	58	39	59	41	22	—	24	—
1 1/2	57	38	59	40	22	—	24	—
1 5/8	57	37	58	39	22	—	24	—
1 3/4	57	37	58	38	22	—	24	—
1 7/8	56	37	58	38	22	—	24	—
2	56	36	58	38	22	—	24	—

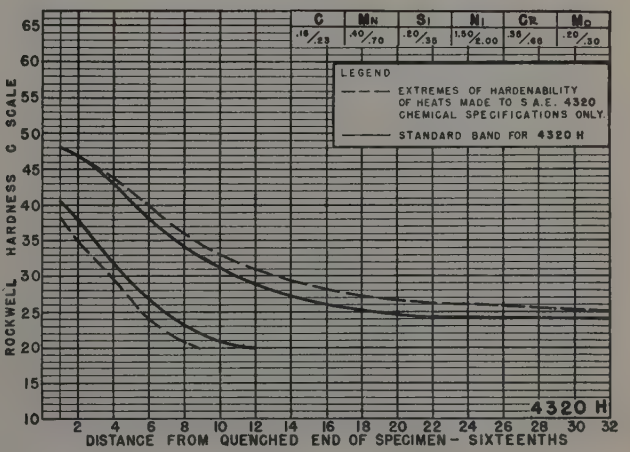
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.


ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
4150 H
C .48/.54 Mn .70/1.05 Si .20/.35 Cr .80/1.15 Mo .15/.25
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 4150 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 4150 H


ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
4317 H
C .14/.21 Mn .40/.70 Si .20/.35 Ni 1.50/2.00 Cr .35/.65 Mo .20/.30


ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
4147 H
C .44/.52 Mn .70/1.05 Si .20/.35 Cr .80/1.15 Mo .15/.25


ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS
4320 H
C .18/.23 Mn .40/.70 Si .20/.35 Ni 1.50/2.00 Cr .35/.65 Mo .20/.30
LEGEND
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 4320 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 4320 H

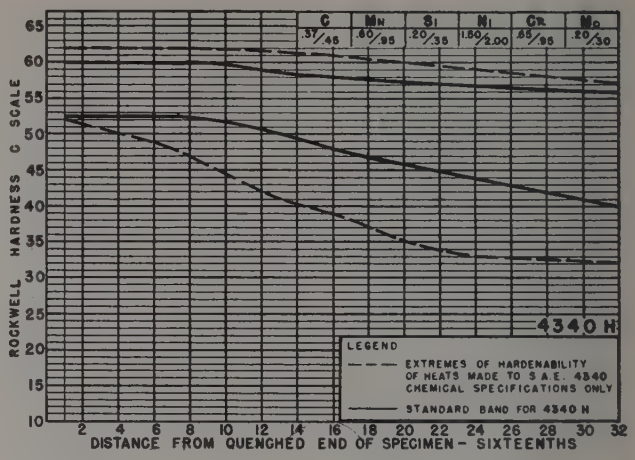
4337 H, 4340 H, 4620 H, X 4620 H

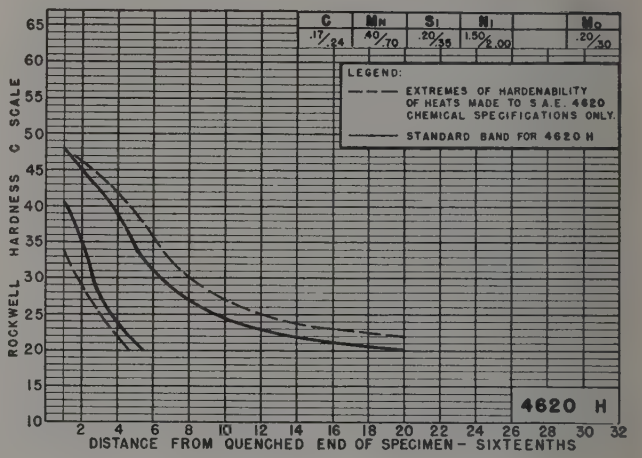
TABLE 3i—*Band Limits for 4337 H, 4340 H, 4620 H, and X4620 H*

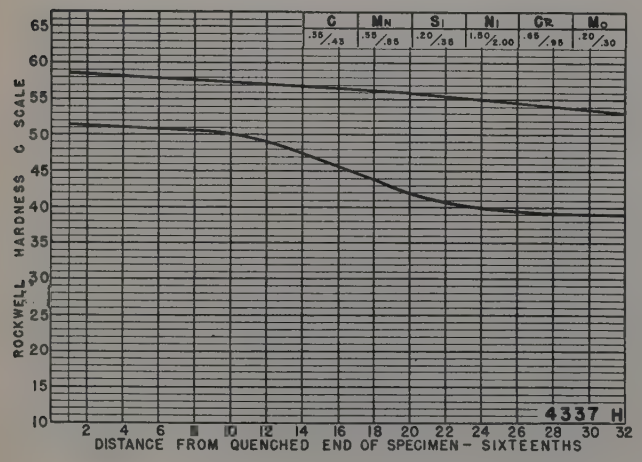
J DISTANCE, IN.	GRADE							
	4337 H		4340 H		4620 H		X4620 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	59	51	60	52	48	40	48	40
1/8	59	51	60	52	45	35	46	38
3/16	58	51	60	52	42	27	44	30
1/4	58	51	60	52	39	24	41	26
5/16	58	51	60	52	34	21	36	23
3/8	58	51	60	52	31	—	32	21
7/16	58	51	60	52	29	—	30	—
1/2	58	50	60	52	27	—	28	—
9/16	58	50	60	52	26	—	27	—
5/8	57	50	60	52	25	—	26	—
11/16	57	50	59	51	24	—	25	—
3/4	57	49	59	51	23	—	24	—
13/16	57	48	59	50	22	—	24	—
7/8	57	47	58	49	22	—	23	—
15/16	57	46	58	49	22	—	23	—
1	57	46	58	48	21	—	23	—
1 1/8	56	44	58	47	21	—	22	—
1 1/4	56	42	57	46	20	—	21	—
1 3/8	55	41	57	45	—	—	21	—
1 1/2	55	40	57	44	—	—	20	—
1 5/8	55	39	57	43	—	—	—	—
1 3/4	54	39	56	42	—	—	—	—
1 7/8	54	39	56	41	—	—	—	—
2	53	39	56	40	—	—	—	—

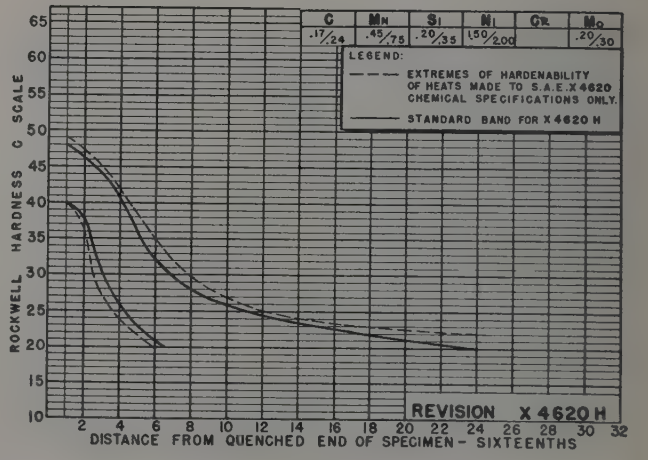
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.








C .17/.24
Mn .45/.75
Si .20/.35
Ni 1.50/2.00
Mo .20/.30
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. X 4620 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR X 4620 H
REVISION X 4620 H
ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS

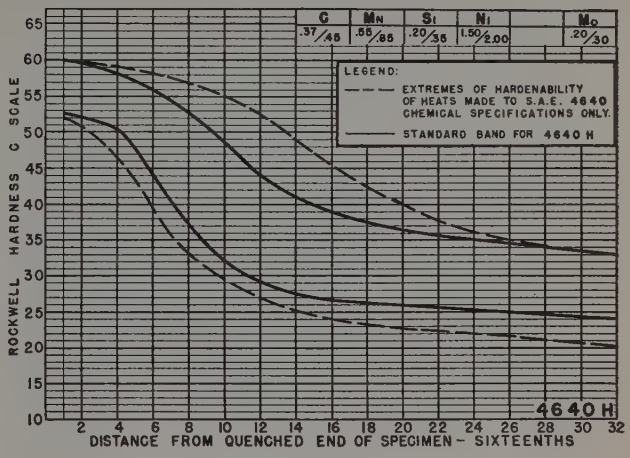
4621 H, 4640 H, 4812 H, 4815 H

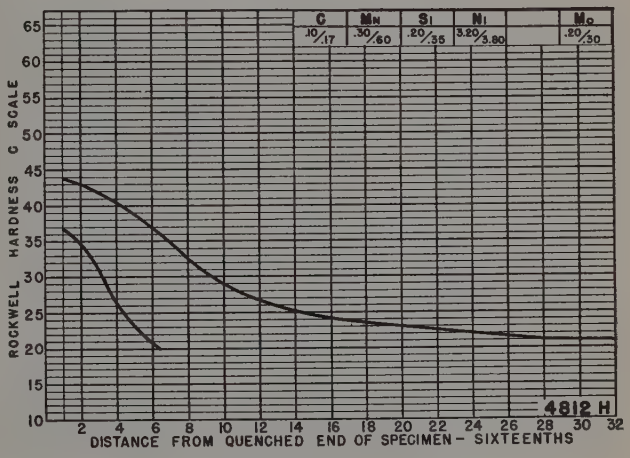
TABLE 3j—*Band Limits for 4621 H, 4640 H, 4812 H, and 4815 H*

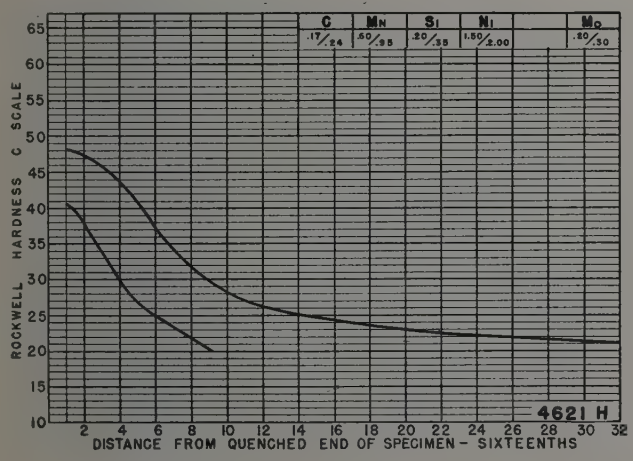
J DISTANCE, IN.	GRADE							
	4621 H		4640 H		4812 H		4815 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	48	40	60	52	44	37	45	38
1/8	47	38	60	52	43	34	44	37
3/16	46	34	59	51	42	30	44	34
1/4	44	30	58	50	41	26	42	30
5/16	41	27	57	48	39	23	41	27
3/8	37	25	56	44	37	21	39	24
7/16	34	23	55	41	35	—	37	22
1/2	32	22	53	37	33	—	35	21
9/16	30	20	51	34	31	—	33	20
5/8	28	—	49	32	29	—	31	—
11/16	27	—	46	30	28	—	30	—
3/4	26	—	44	29	27	—	29	—
13/16	26	—	42	28	26	—	28	—
7/8	25	—	41	27	25	—	28	—
15/16	25	—	40	27	25	—	27	—
1	24	—	39	27	24	—	27	—
1 1/8	24	—	38	26	24	—	26	—
1 1/4	23	—	37	26	23	—	25	—
1 3/8	23	—	36	26	23	—	24	—
1 1/2	22	—	35	25	22	—	24	—
1 5/8	22	—	35	25	22	—	24	—
1 3/4	22	—	34	25	21	—	23	—
1 7/8	21	—	34	24	21	—	23	—
2	21	—	33	24	21	—	23	—

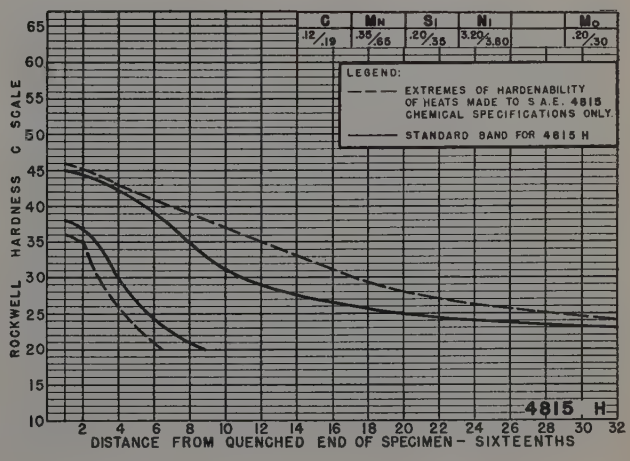
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









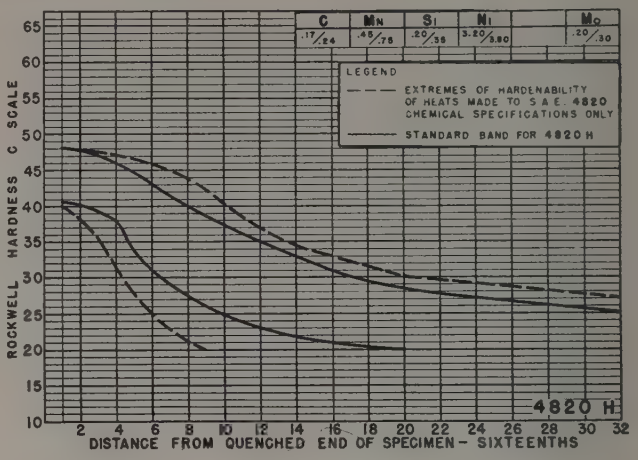
4817 H, 4820 H, 5120 H, 5130 H

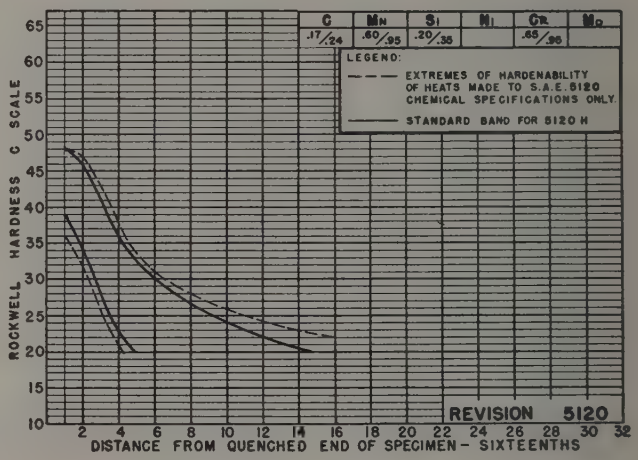
TABLE 3k—*Band Limits for 4817 H, 4820 H, 5120 H, and 5130 H*

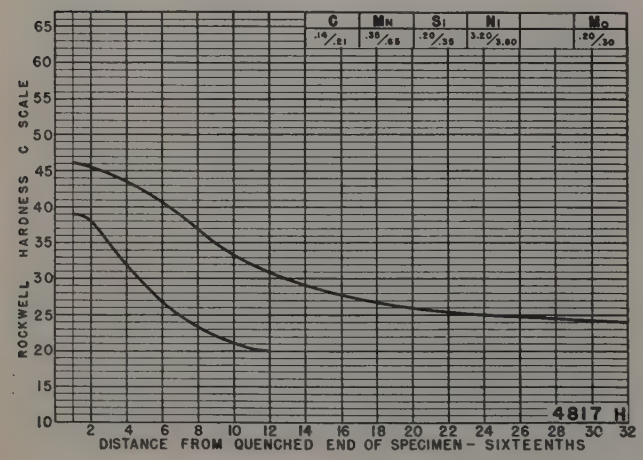
J DISTANCE, IN.	GRADE							
	4817 H		4820 H		5120 H		5130 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	46	39	48	40	48	39	54	46
1/8	46	38	48	40	46	34	54	46
3/16	45	35	47	39	41	28	53	42
1/4	44	32	46	38	36	23	51	39
5/16	42	29	45	34	33	20	49	35
3/8	41	27	43	31	30	—	47	32
7/16	39	25	42	29	28	—	45	30
1/2	37	23	40	27	27	—	42	28
9/16	35	22	39	26	25	—	40	26
5/8	33	21	37	25	24	—	38	25
11/16	32	20	36	24	23	—	37	23
3/4	31	20	35	23	22	—	36	22
13/16	30	—	34	22	21	—	35	21
7/8	30	—	33	22	21	—	34	20
15/16	28	—	32	21	20	—	34	—
1	28	—	31	21	—	—	33	—
1 1/8	27	—	29	20	—	—	32	—
1 1/4	26	—	28	20	—	—	31	—
1 3/8	25	—	28	—	—	—	30	—
1 1/2	25	—	27	—	—	—	29	—
1 5/8	25	—	27	—	—	—	27	—
1 3/4	25	—	26	—	—	—	26	—
1 7/8	24	—	26	—	—	—	25	—
2	24	—	25	—	—	—	24	—

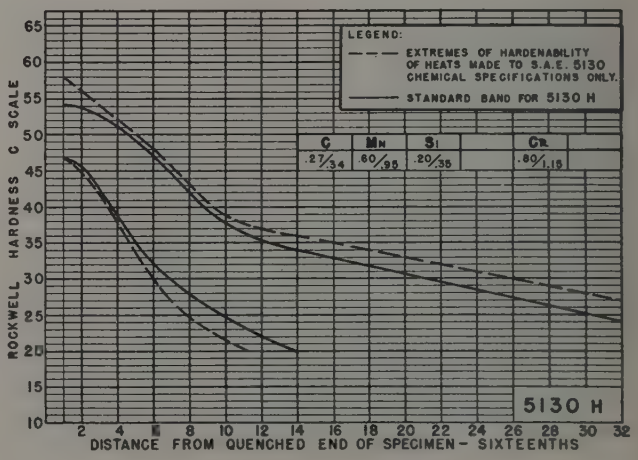
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.








LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 5130 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 5130 H
C .27/.34
Mn .60/.95
Si .20/.35
Cr .80/1.15
ROCKWELL HARDNESS C SCALE
5130 H
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS

5132 H, 5135 H, 5140 H, 5145 H

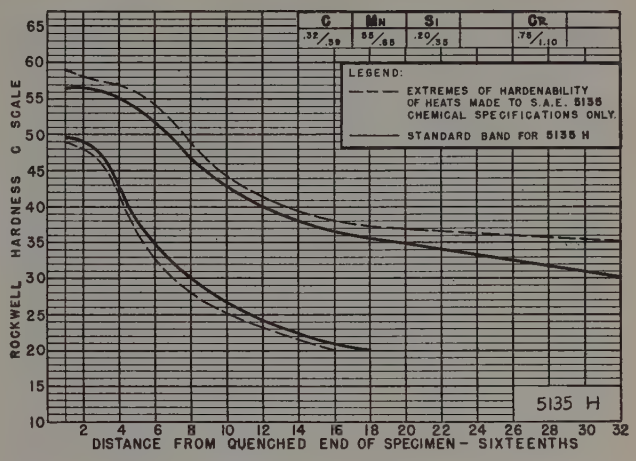
TABLE 31—*Band Limits for 5132 H, 5135 H, 5140 H, and 5145 H*

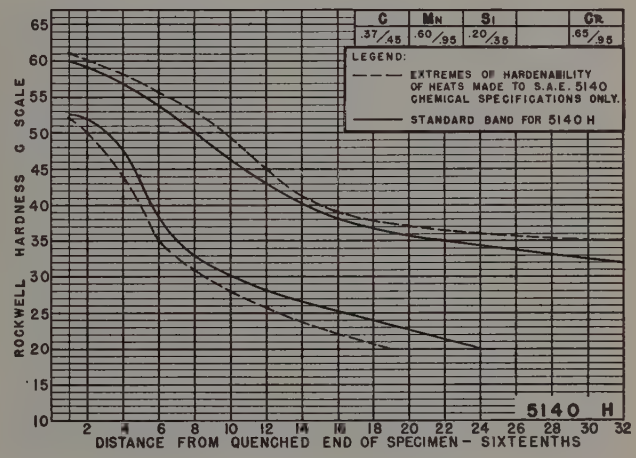
J DISTANCE, IN.	GRADE							
	5132 H[a]		5135 H		5140 H		5145 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	55	47	57	49	60	52	63	55
1/8	54	46	57	49	59	52	62	54
3/16	53	43	56	47	58	50	61	53
1/4	52	40	55	43	57	48	60	51
5/16	50	35	54	38	56	43	59	48
3/8	48	32	52	35	54	38	58	42
7/16	45	29	50	32	52	35	57	38
1/2	42	27	47	30	50	33	56	35
9/16	40	25	45	28	48	31	55	33
5/8	38	24	43	27	46	30	53	32
11/16	37	23	41	25	45	29	52	31
3/4	36	22	40	24	43	28	50	30
13/16	35	21	39	23	42	27	48	30
7/8	34	20	38	22	40	27	47	29
15/16	34	—	37	21	39	26	45	28
1	33	—	37	21	38	25	44	28
1 1/8	32	—	36	20	37	24	42	26
1 1/4	31	—	35	—	36	23	41	25
1 3/8	30	—	34	—	35	21	39	24
1 1/2	29	—	33	—	34	20	38	23
1 5/8	28	—	32	—	34	—	37	22
1 3/4	27	—	32	—	33	—	37	21
1 7/8	26	—	31	—	33	—	36	—
2	25	—	30	—	32	—	35	—

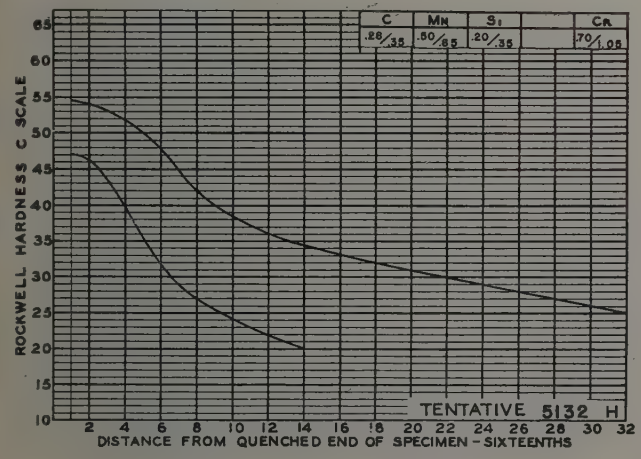
[a] Tentative.

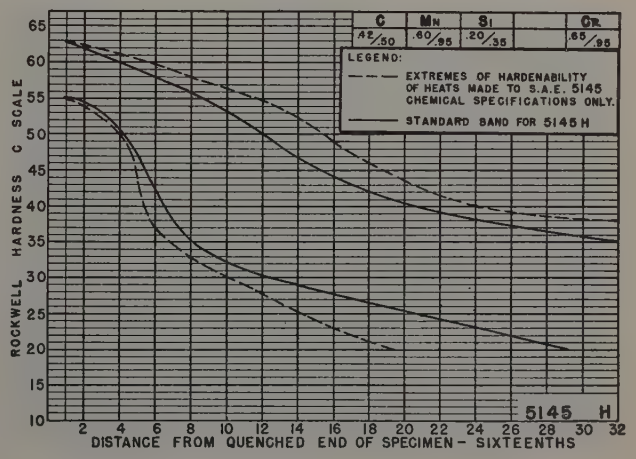
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.


C .32/.39
Mn .55/.85
Si .20/.35
Cr .75/1.10
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 5135 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 5135 H
ROCKWELL HARDNESS C SCALE
5135 H
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS


C .37/.45
Mn .60/.95
Si .20/.35
Cr .65/.95
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 5140 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 5140 H
ROCKWELL HARDNESS C SCALE
5140 H
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS




C .42/.50
Mn .60/.95
Si .20/.35
Cr .65/.95
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 5145 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 5145 H
ROCKWELL HARDNESS C SCALE
5145 H
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS

5147 H, 5150 H, 5152 H, 5160 H

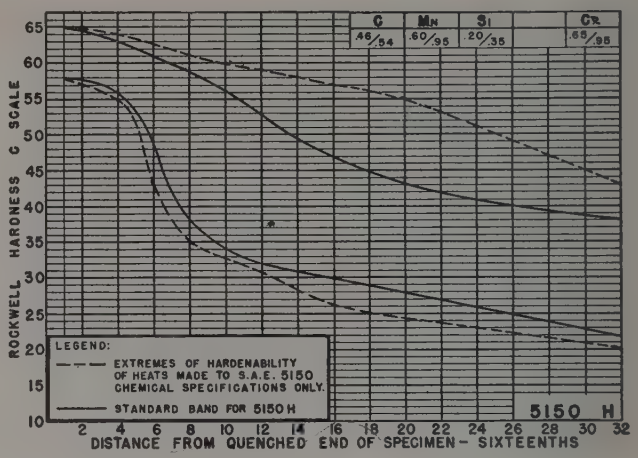
TABLE 3m—*Band Limits for 5147 H, 5150 H, 5152 H, and 5160 H*

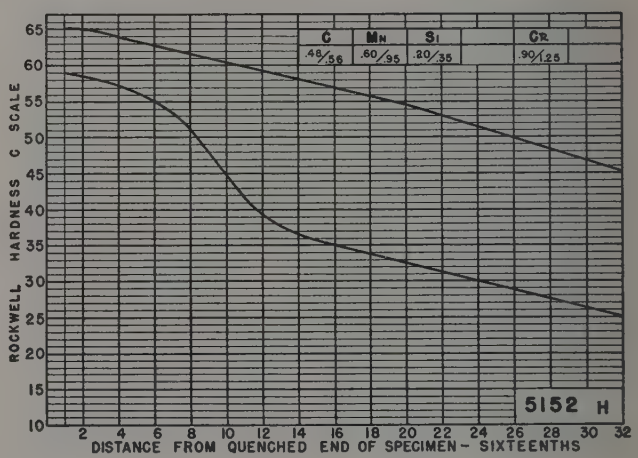
J DISTANCE, IN.	GRADE							
	5147 H[a]		5150 H		5152 H		5160 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	64	56	65	58	65	59	—	60
1/8	64	56	65	58	65	58	—	60
3/16	63	55	64	57	65	58	—	60
1/4	62	54	63	56	64	57	65	59
5/16	62	53	62	53	63	56	65	58
3/8	61	52	61	49	63	55	64	56
7/16	61	49	60	42	62	53	64	52
1/2	60	45	59	38	62	51	63	47
9/16	60	40	58	36	61	48	62	42
5/8	59	37	56	34	60	45	61	39
11/16	59	35	55	33	60	42	60	37
3/4	58	34	53	32	59	39	59	36
13/16	58	33	51	31	59	38	58	35
7/8	57	32	50	31	58	37	56	35
15/16	57	32	48	30	58	36	54	34
1	56	31	47	30	57	35	52	34
1 1/8	55	30	45	29	56	34	48	33
1 1/4	54	29	43	28	55	32	47	32
1 3/8	53	27	42	27	53	31	46	31
1 1/2	52	26	41	26	51	30	45	30
1 5/8	51	25	40	25	50	29	44	29
1 3/4	50	24	39	24	48	27	43	28
1 7/8	49	22	39	23	47	26	43	28
2	48	21	38	22	45	25	42	27

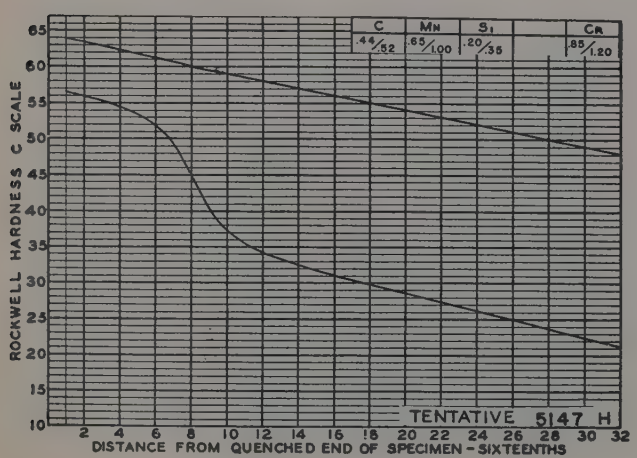
[a] Tentative.

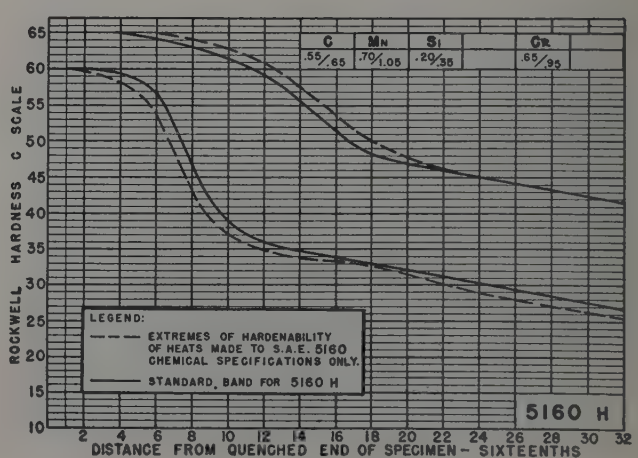
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.


C .46/.54
Mn .60/.95
Si .20/.35
Cr .65/.95
ROCKWELL HARDNESS C SCALE
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 5150 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 5150 H
5150 H
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS






C .55/.65
Mn .70/1.05
Si .20/.35
Cr .65/.95
ROCKWELL HARDNESS C SCALE
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 5160 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 5160 H
5160 H
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS

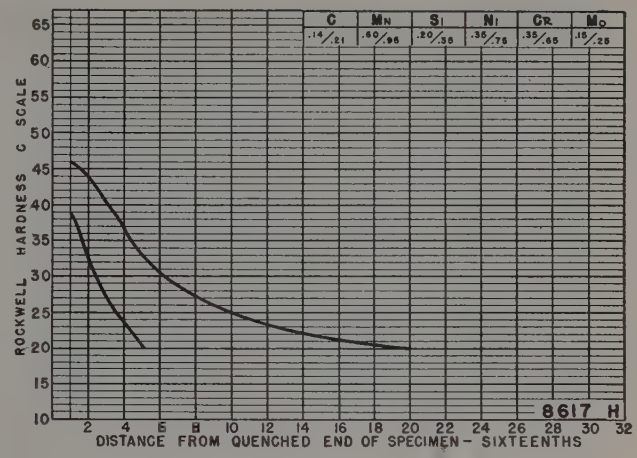
6150 H, 8617 H, 8620 H, 8622 H

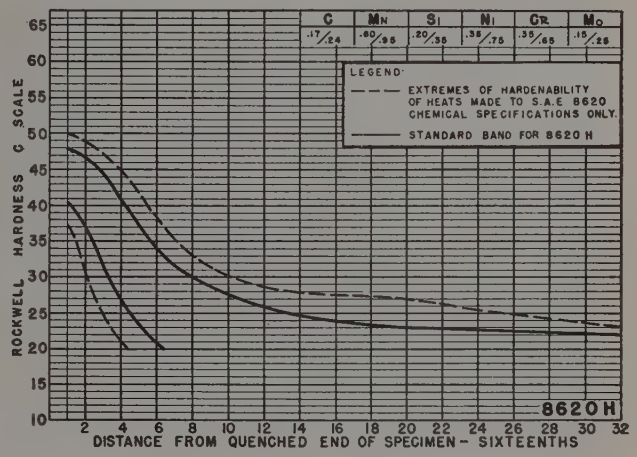
TABLE 3n—*Band Limits for 6150 H, 8617 H, 8620 H, and 8622 H*

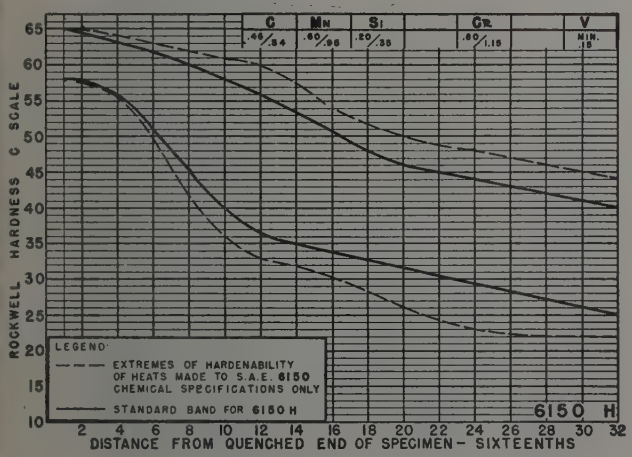
J DISTANCE, IN.	GRADE							
	6150 H		8617 H		8620 H		8622 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	65	58	46	39	48	40	50	42
1/8	65	58	44	33	47	37	49	39
3/16	64	57	41	27	44	32	47	34
1/4	63	56	38	24	41	27	44	30
5/16	63	54	34	20	37	23	40	26
3/8	62	51	31	—	34	21	37	24
7/16	61	48	28	—	32	—	34	22
1/2	60	45	27	—	30	—	32	20
9/16	59	43	26	—	29	—	31	—
5/8	58	40	25	—	28	—	30	—
11/16	57	38	24	—	27	—	29	—
3/4	56	36	23	—	26	—	28	—
13/16	55	35	23	—	25	—	27	—
7/8	54	35	22	—	25	—	26	—
15/16	52	34	22	—	24	—	26	—
1	51	34	21	—	24	—	25	—
1 1/8	48	33	21	—	23	—	25	—
1 1/4	46	32	20	—	23	—	24	—
1 3/8	45	30	—	—	23	—	24	—
1 1/2	44	29	—	—	23	—	24	—
1 5/8	43	28	—	—	23	—	24	—
1 3/4	42	27	—	—	22	—	24	—
1 7/8	41	26	—	—	22	—	24	—
2	40	25	—	—	22	—	24	—

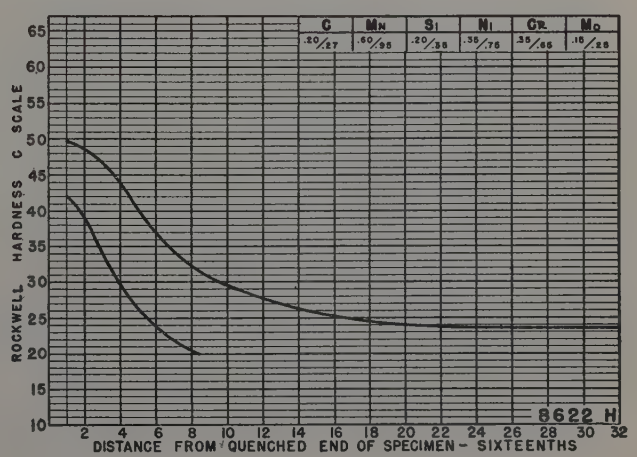
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









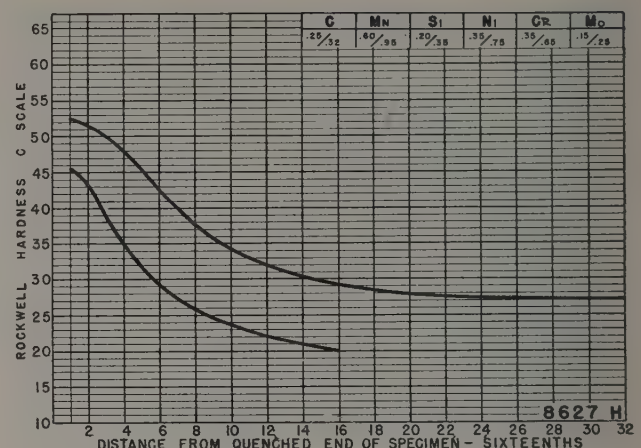
8625 H, 8627 H, 8630 H, 8632 H

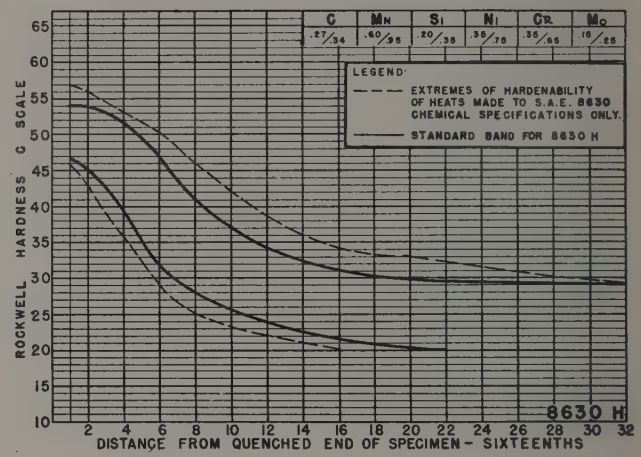
TABLE 3o—*Band Limits for 8625 H, 8627 H, 8630 H, and 8632 H*

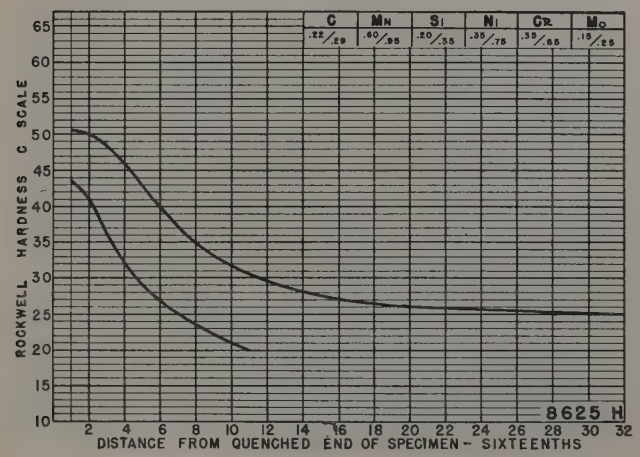
J DISTANCE, IN.	GRADE							
	8625 H		8627 H		8630 H		8632 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	51	43	53	45	54	46	56	48
1/8	50	41	52	43	54	45	55	46
3/16	48	36	50	38	53	42	54	44
1/4	46	32	48	35	52	39	53	42
5/16	43	29	45	32	50	35	51	38
3/8	40	27	43	29	47	32	49	35
7/16	37	25	40	27	44	29	46	32
1/2	35	23	38	26	41	28	43	30
9/16	33	22	36	24	39	27	41	28
5/8	32	21	34	24	37	26	39	27
11/16	31	20	33	23	35	25	37	26
3/4	30	—	32	22	34	24	36	25
13/16	29	—	31	21	33	23	35	24
7/8	28	—	30	21	33	22	35	24
15/16	28	—	30	20	32	22	34	23
1	27	—	29	20	31	21	33	23
1 1/8	27	—	28	—	30	21	32	22
1 1/4	26	—	28	—	30	20	32	21
1 3/8	26	—	28	—	29	20	31	21
1 1/2	26	—	27	—	29	—	31	21
1 5/8	26	—	27	—	29	—	31	20
1 3/4	25	—	27	—	29	—	31	20
1 7/8	25	—	27	—	29	—	31	—
2	25	—	27	—	29	—	31	—

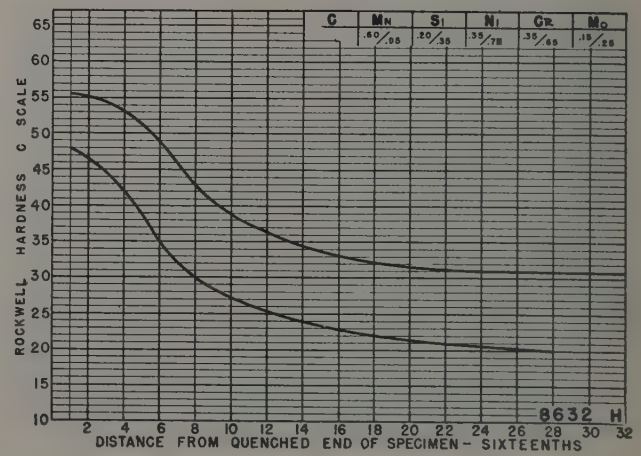
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









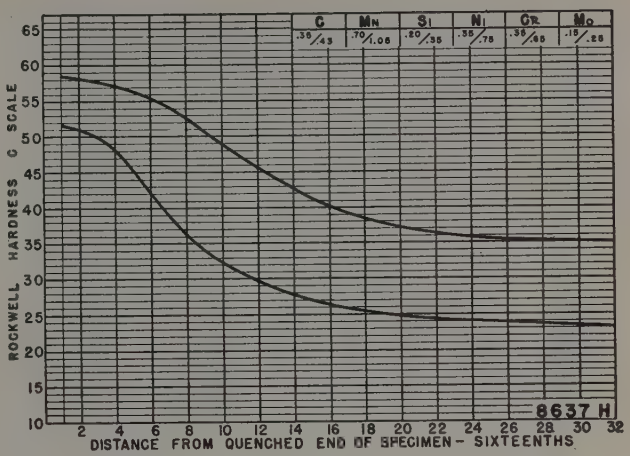
8635 H, 8637 H, 8640 H, 8641 H, 8642 H

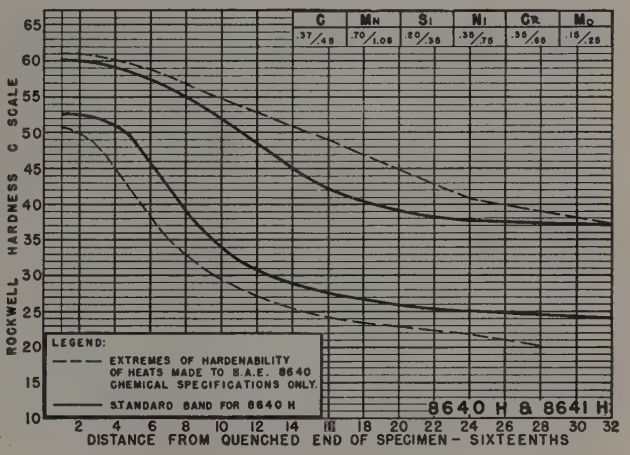
TABLE 3p—*Band Limits for 8635 H, 8637 H, 8640 H, 8641 H, and 8642 H*

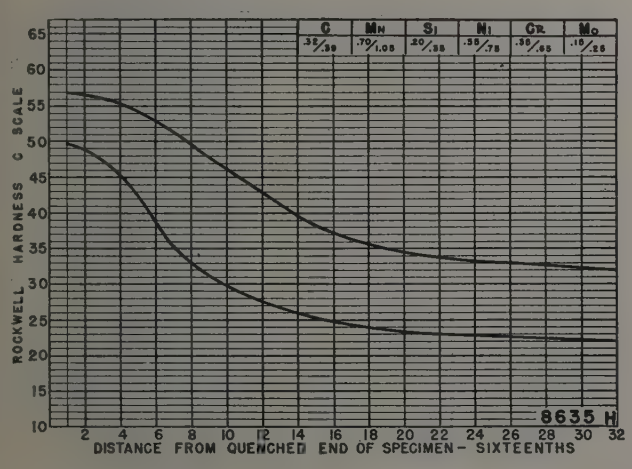
J DISTANCE, IN.	GRADE							
	8635 H		8637 H		8640 H 8641 H		8642 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	57	49	59	51	60	52	62	54
1/8	57	49	58	51	60	52	62	54
3/16	56	47	58	50	60	52	62	53
1/4	55	45	57	48	59	51	61	52
5/16	54	42	56	45	59	49	61	50
3/8	53	39	55	42	58	46	60	48
7/16	51	35	54	39	57	42	59	45
1/2	50	33	53	36	55	39	58	42
9/16	48	31	51	34	54	36	57	39
5/8	46	30	49	32	52	34	55	37
11/16	45	29	47	31	50	32	54	34
3/4	43	28	46	30	49	31	52	33
13/16	41	27	44	29	47	30	50	32
7/8	40	26	43	28	45	29	49	31
15/16	38	25	41	27	44	28	48	30
1	37	25	40	26	42	28	46	29
1 1/8	36	24	39	25	41	26	44	28
1 1/4	35	23	37	25	39	26	42	28
1 3/8	34	23	36	24	38	25	41	27
1 1/2	33	23	36	24	38	25	40	27
1 5/8	33	23	35	24	37	24	40	26
1 3/4	33	22	35	24	37	24	39	26
1 7/8	32	22	35	23	37	24	39	26
2	32	22	35	23	37	24	39	26

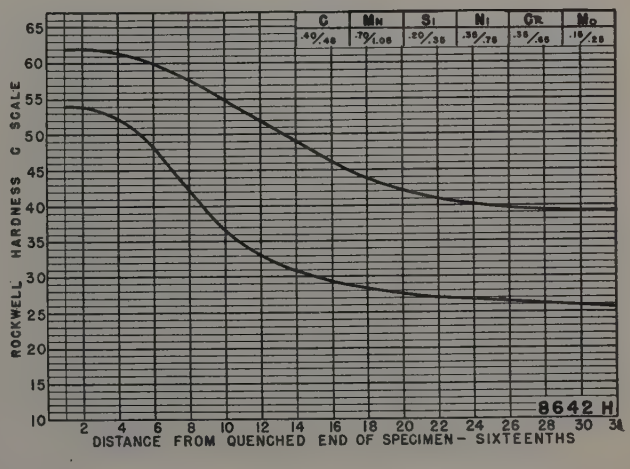
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









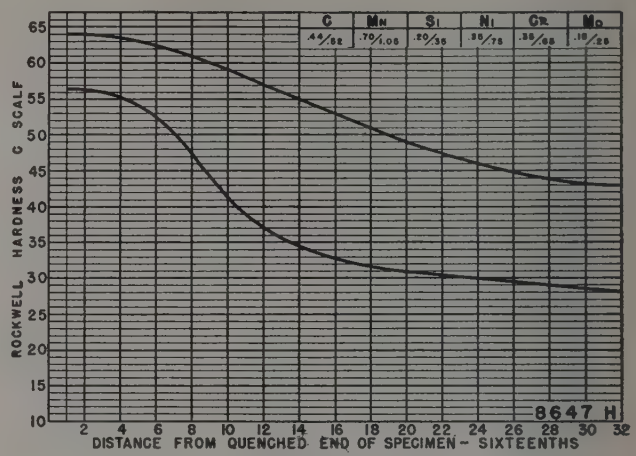
8645 H, 8647 H, 8650 H, 8653 H

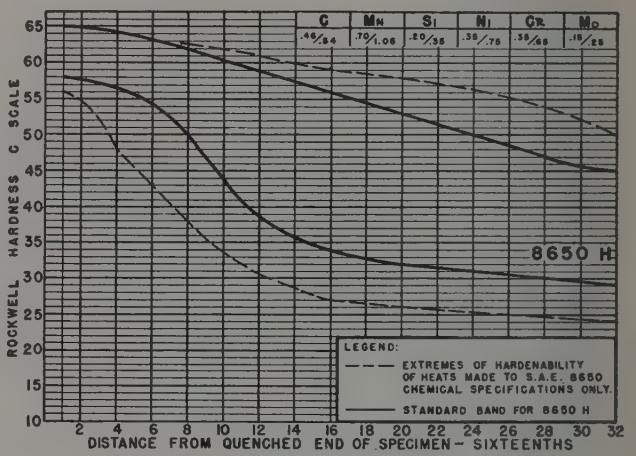
TABLE 3q—*Band Limits for 8645 H, 8647 H, 8650 H, and 8653 H*

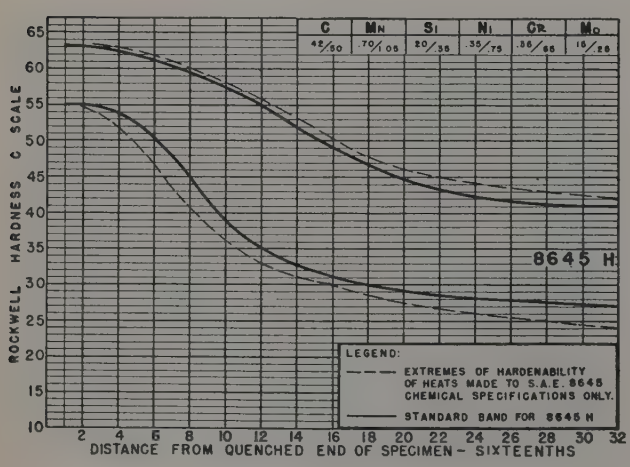
J DISTANCE, IN.	GRADE							
	8645 H		8647 H		8650 H		8653 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	63	55	64	56	65	58	65	59
1/8	63	55	64	56	65	58	65	59
3/16	63	55	64	56	65	57	65	59
1/4	63	54	64	55	64	57	65	58
5/16	62	52	63	54	64	56	65	58
3/8	61	50	62	52	63	54	64	57
7/16	61	48	62	50	63	53	64	57
1/2	60	45	61	47	62	50	64	56
9/16	59	41	60	44	61	47	63	55
5/8	58	39	59	41	60	44	63	53
11/16	56	37	58	39	60	41	63	49
3/4	55	35	57	37	59	39	62	47
13/16	54	34	56	35	58	37	62	45
7/8	52	33	55	34	58	36	62	44
15/16	51	32	54	33	57	35	62	43
1	49	31	53	33	56	34	61	42
1 1/8	47	30	51	32	55	33	61	40
1 1/4	45	29	49	31	53	32	60	39
1 3/8	43	28	48	30	52	31	59	38
1 1/2	42	28	46	30	50	31	59	37
1 5/8	42	27	45	29	49	30	59	36
1 3/4	41	27	44	29	47	30	59	35
1 7/8	41	27	43	28	46	29	58	35
2	41	27	43	28	45	29	58	34

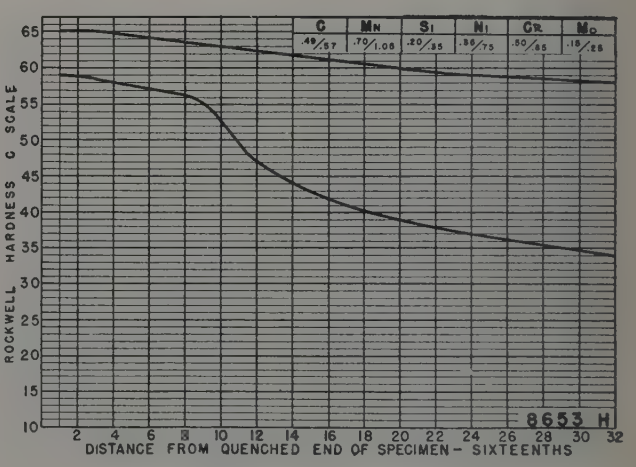
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









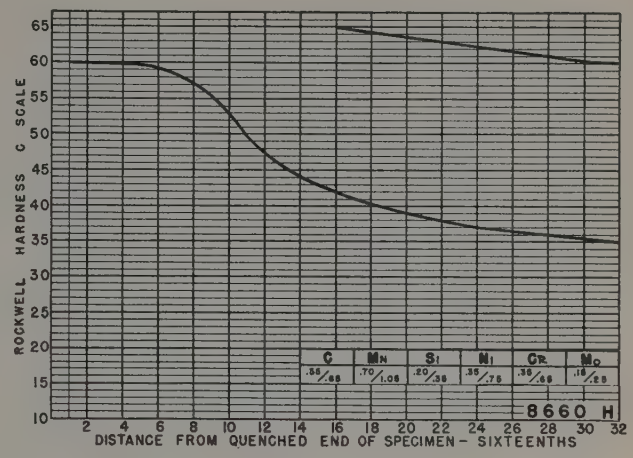
8655 H, 8660 H, 8720 H, 8735 H

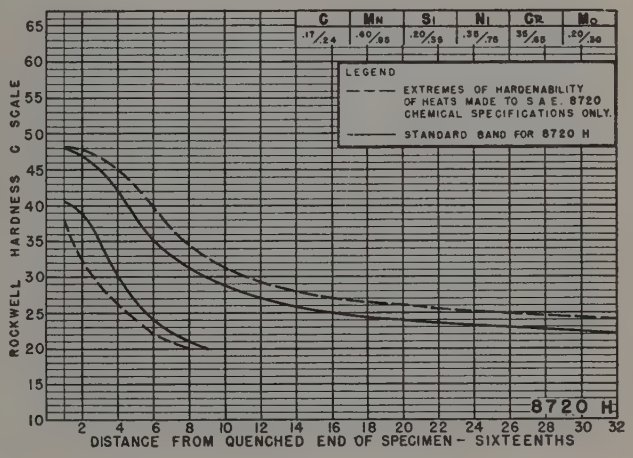
TABLE 3r—*Band Limits for 8655 H, 8660 H, 8720 H, and 8735 H*

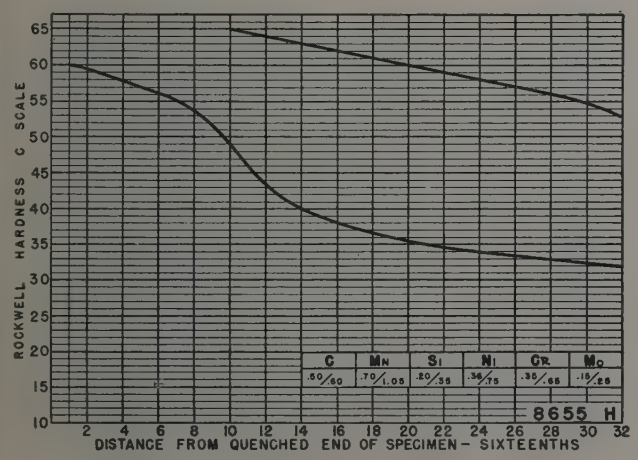
J DISTANCE, IN.	GRADE							
	8655 H		8660 H		8720 H		8735 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	—	60	—	60	48	40	57	49
1/8	—	59	—	60	47	38	57	49
3/16	—	59	—	60	45	35	57	49
1/4	—	58	—	60	42	30	56	48
5/16	—	57	—	60	38	26	55	45
3/8	—	56	—	59	35	24	54	41
7/16	—	55	—	58	33	22	53	37
1/2	—	54	—	57	31	21	51	35
9/16	—	52	—	55	30	20	49	33
5/8	65	49	—	53	29	—	48	31
11/16	65	46	—	50	28	—	46	30
3/4	64	43	—	47	27	—	45	29
13/16	64	41	—	45	26	—	44	28
7/8	63	40	—	44	26	—	42	27
15/16	63	39	—	43	25	—	41	26
1	62	38	65	42	25	—	39	26
1 1/8	61	37	64	40	24	—	38	25
1 1/4	60	35	64	39	24	—	36	25
1 3/8	59	34	63	38	23	—	36	24
1 1/2	58	34	62	37	23	—	35	24
1 5/8	57	33	62	36	23	—	35	24
1 3/4	56	33	61	36	23	—	35	23
1 7/8	55	32	60	35	22	—	35	23
2	53	32	60	35	22	—	35	23

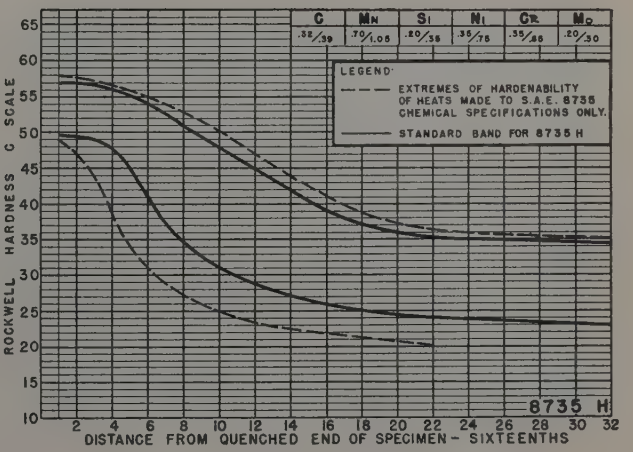
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.


ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN – SIXTEENTHS
C .55/.65 | MN .70/1.05 | SI .20/.35 | NI .35/.75 | CR .35/.65 | MO .15/.25
8660 H


ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN – SIXTEENTHS
C .17/.24 | MN .60/.95 | SI .20/.35 | NI .35/.75 | CR .35/.65 | MO .20/.30
LEGEND
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 8720 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 8720 H
8720 H


ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN – SIXTEENTHS
C .50/.60 | MN .70/1.05 | SI .20/.35 | NI .35/.75 | CR .35/.65 | MO .15/.25
8655 H


ROCKWELL HARDNESS C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN – SIXTEENTHS
C .32/.39 | MN .70/1.05 | SI .20/.35 | NI .35/.75 | CR .35/.65 | MO .20/.30
LEGEND
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 8735 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 8735 H
8735 H

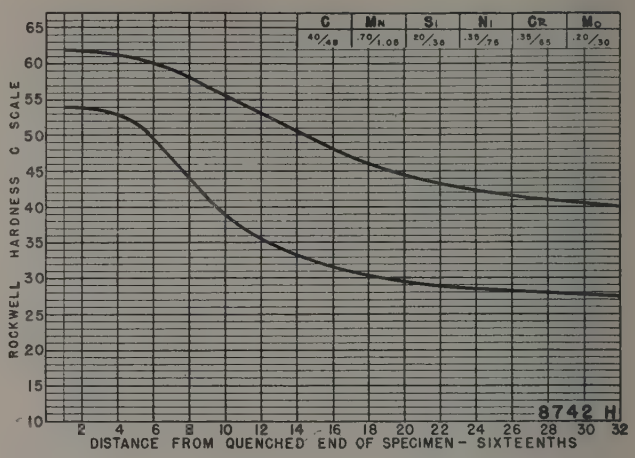
8740 H, 8742 H, 8745 H, 8747 H

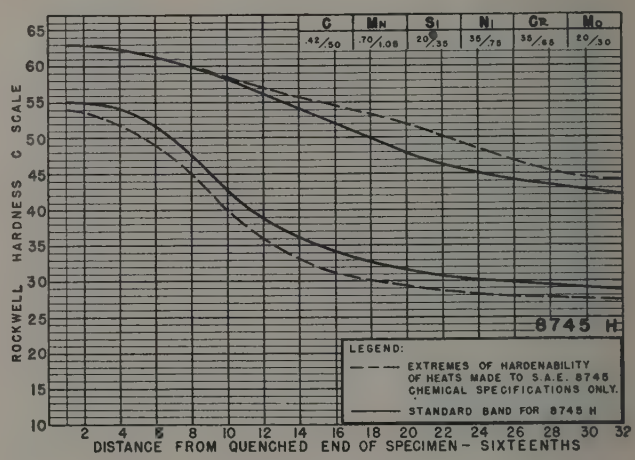
TABLE 3s—*Band Limits for 8740 H, 8742 H, 8745 H, and 8747 H*

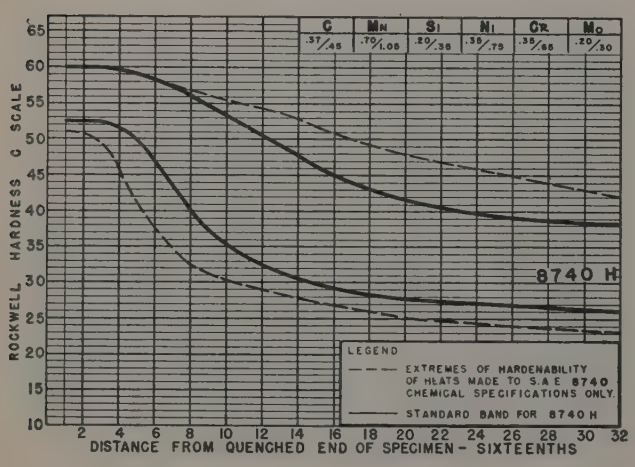
J DISTANCE, IN.	GRADE							
	8740 H		8742 H		8745 H		8747 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	60	52	62	54	63	55	64	56
1/8	60	52	62	54	63	55	64	56
3/16	60	52	62	54	63	55	64	56
1/4	60	51	61	53	62	54	63	55
5/16	59	49	61	52	62	53	63	55
3/8	58	46	60	49	61	52	62	54
7/16	57	43	59	47	61	49	62	52
1/2	56	40	58	44	60	47	61	50
9/16	55	37	57	41	59	45	60	48
5/8	53	35	56	39	58	43	59	46
11/16	52	34	54	37	57	40	59	44
3/4	50	32	53	35	56	39	58	42
13/16	49	31	52	34	55	37	57	40
7/8	48	31	51	33	54	36	57	39
15/16	46	30	49	32	53	35	56	37
1	45	29	48	31	52	34	55	36
1 1/8	43	28	46	30	50	33	53	34
1 1/4	42	28	45	29	48	32	52	33
1 3/8	41	27	43	29	46	31	50	32
1 1/2	40	27	42	28	45	30	49	32
1 5/8	39	27	42	28	44	30	47	31
1 3/4	39	27	41	28	44	29	46	31
1 7/8	38	26	41	28	43	29	46	31
2	38	26	40	27	42	29	45	30

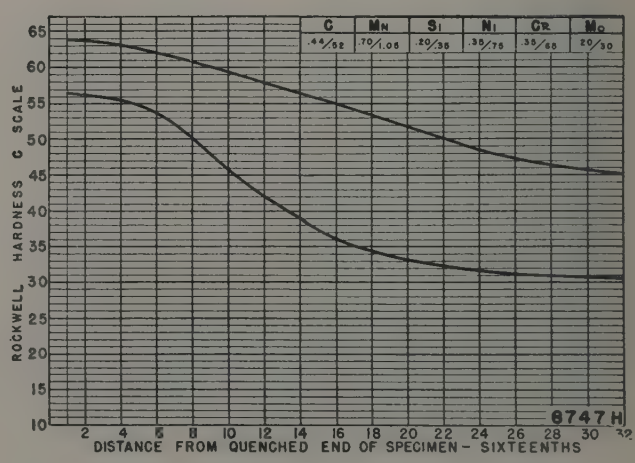
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









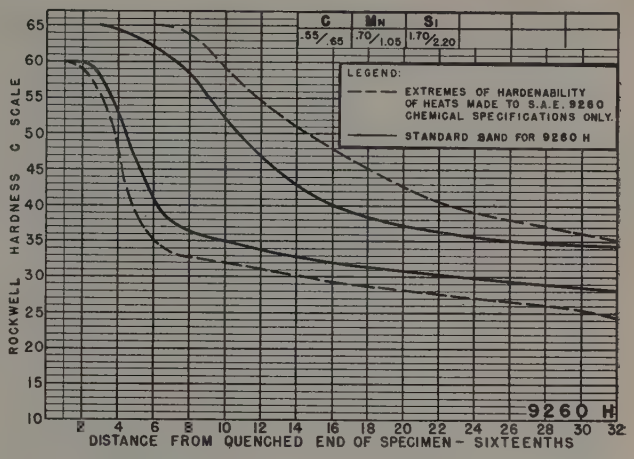
8750 H, 9260 H, 9261 H, 9262 H

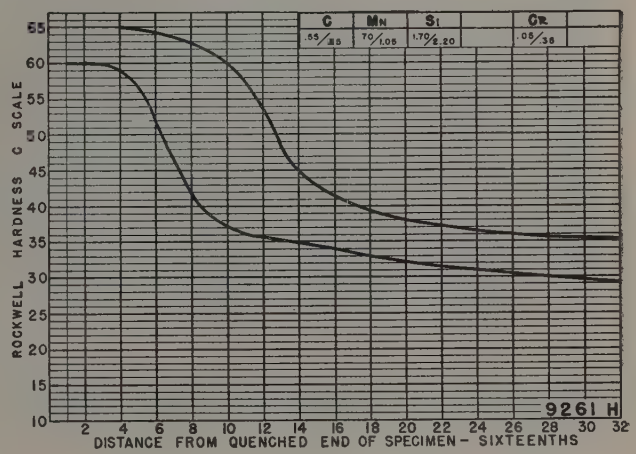
TABLE 3t—*Band Limits for 8750 H, 9260 H, 9261 H, and 9262 H*

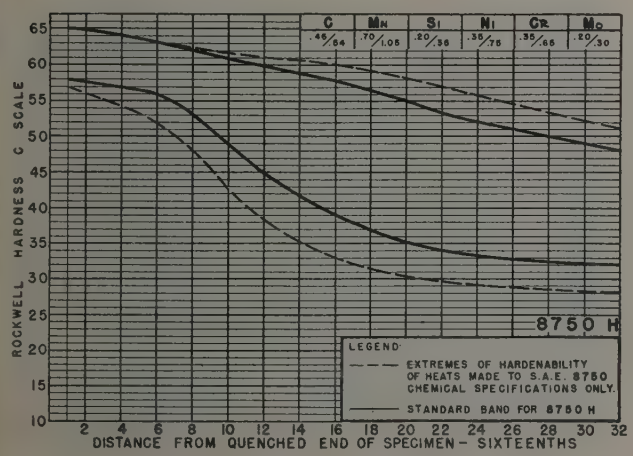
J DISTANCE, IN.	GRADE							
	8750 H		9260 H		9261 H		9262 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	65	58	—	60	—	60	—	60
1/8	65	58	—	60	—	60	—	60
3/16	65	57	65	57	—	60	—	60
1/4	64	57	64	53	65	59	—	60
5/16	64	56	63	46	65	56	—	58
3/8	63	56	62	41	64	52	65	56
7/16	63	55	60	38	64	47	65	53
1/2	62	53	58	36	63	42	64	48
9/16	62	51	55	36	62	39	63	42
5/8	61	49	52	35	60	37	62	39
11/16	60	47	49	34	57	36	61	37
3/4	60	45	47	34	54	36	59	37
13/16	59	43	45	33	49	35	57	36
7/8	59	42	43	33	45	35	55	36
15/16	58	40	42	32	43	34	51	35
1	58	39	40	32	42	34	48	35
1 1/8	57	37	38	31	39	33	45	34
1 1/4	55	35	37	31	38	32	43	33
1 3/8	53	34	36	30	37	31	41	33
1 1/2	52	33	36	30	37	31	39	32
1 5/8	51	33	35	29	36	30	38	31
1 3/4	50	32	35	29	36	30	37	31
1 7/8	49	32	35	28	35	29	36	30
2	48	32	34	28	35	29	36	30

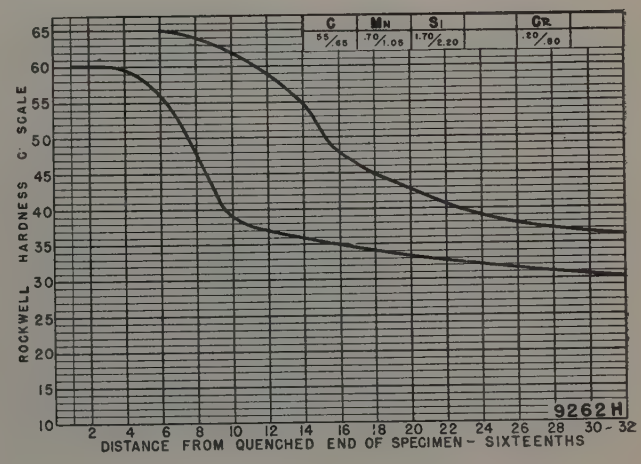
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.


C .55/.65
Mn .70/1.05
Si 1.70/2.20
LEGEND:
EXTREMES OF HARDENABILITY OF HEATS MADE TO S.A.E. 9260 CHEMICAL SPECIFICATIONS ONLY.
STANDARD BAND FOR 9260 H
ROCKWELL HARDNESS C SCALE
9260 H
DISTANCE FROM QUENCHED END OF SPECIMEN - SIXTEENTHS







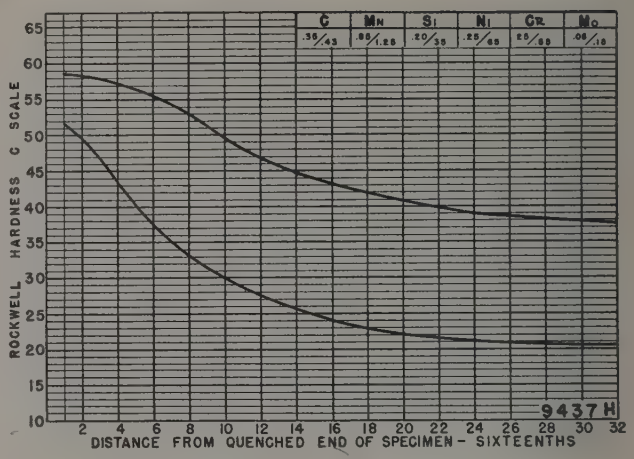
9310 H, 9437 H, 9440 H, 9442 H

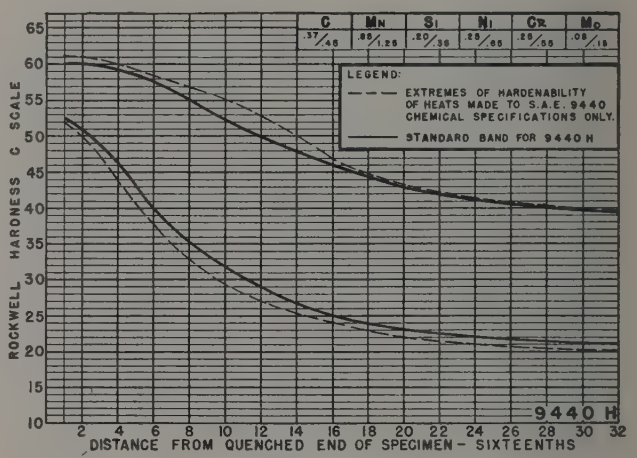
TABLE 3u—*Band Limits for 9310 H, 9437 H, 9440 H, and 9442 H*

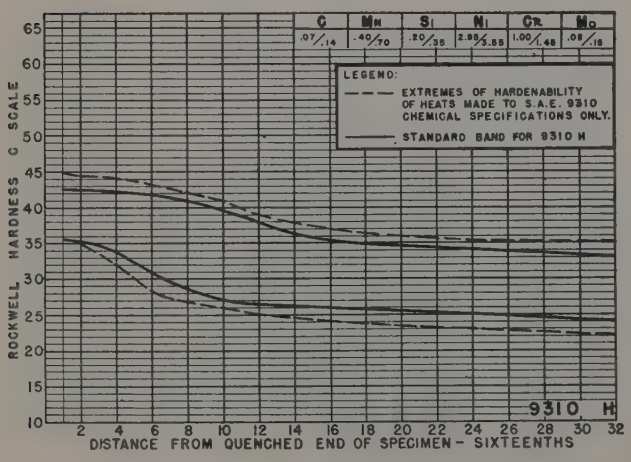
J DISTANCE, IN.	GRADE							
	9310 H		9437 H		9440 H		9442 H	
	Max	Min	Max	Min	Max	Min	Max	Min
1/16	43	35	59	51	60	52	62	54
1/8	43	35	58	49	60	51	62	52
3/16	43	35	58	47	60	49	62	51
1/4	42	34	57	43	59	46	61	48
5/16	42	32	57	40	59	43	61	45
3/8	42	31	56	37	58	40	60	43
7/16	42	30	55	35	57	37	59	40
1/2	41	29	53	33	55	35	59	38
9/16	40	28	51	31	54	33	58	36
5/8	40	27	50	30	52	32	57	34
11/16	39	27	48	28	51	30	55	32
3/4	38	26	47	27	50	29	54	31
13/16	37	26	46	26	49	28	53	30
7/8	36	26	45	26	48	27	52	29
15/16	36	26	44	25	47	26	51	28
1	35	26	43	24	46	25	50	27
1 1/8	35	26	42	23	45	24	48	26
1 1/4	35	25	41	22	43	23	47	25
1 3/8	34	25	40	21	42	22	46	25
1 1/2	34	25	39	21	41	22	45	24
1 5/8	34	25	39	21	41	22	44	24
1 3/4	34	25	38	20	40	21	43	24
1 7/8	33	24	38	20	40	21	43	24
2	33	24	38	20	39	21	43	23

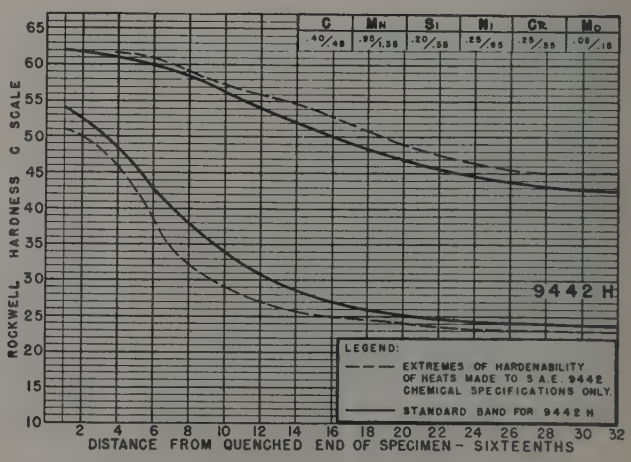
Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.









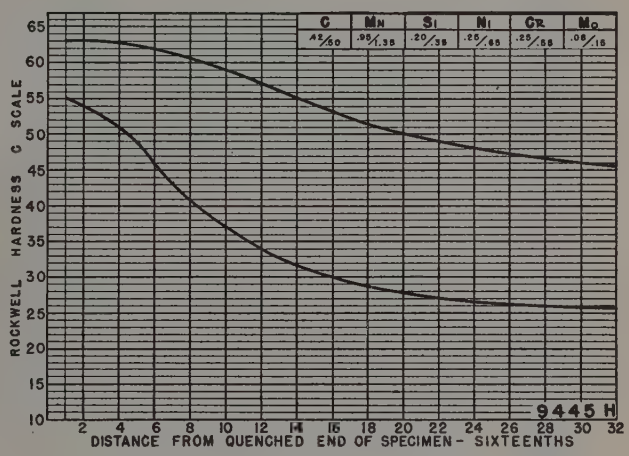
9445 H

TABLE 3v—*Band Limits for 9445 H*

J DISTANCE, IN.	GRADE 9445 H Max	GRADE 9445 H Min
1/16	63	55
1/8	63	54
3/16	63	53
1/4	63	51
5/16	62	49
3/8	62	46
7/16	62	43
1/2	61	41
9/16	60	39
5/8	59	37
11/16	58	35
3/4	57	34
13/16	56	33
7/8	55	32
15/16	54	31
1	53	30
1 1/8	52	29
1 1/4	50	28
1 3/8	49	27
1 1/2	48	26
1 5/8	47	26
1 3/4	46	26
1 7/8	46	26
2	45	26

Tabulated values have been adjusted to the nearest Rockwell C unit and are to be used when points are selected and specified.

For chemical compositions, see Tables 1 and 2.



Chemical Compositions of SAE Wrought Stainless Steels

SAE Standard

From report of Iron and Steel Division approved June 1911 and last revised by Iron and Steel Technical Committee January 1950.

TABLE 1—*Wrought Chromium-Nickel Austenitic Steels (Not Capable of Heat-Treatment)*

SAE Number	CHEMICAL COMPOSITION LIMITS, %								AISI TYPE
	C	Max. Mn	Max. Si	Max. P	Max. S	Cr range	Ni range	Other elements	
30301	0.08–0.15	2.00	1.00	0.04	0.03	16.00–18.00	6.00– 8.00	—	301
30302	0.08–0.15	2.00	1.00	0.04	0.03	17.00–19.00	7.00–10.00	—	302
30303F	0.15 max.	2.00	1.00	—	—	17.00–19.00	8.00–10.00	P, S, Se min. 0.07 Zr, Mo max. 0.60	303
30304	0.08 max.	2.00	1.00	0.04	0.03	18.00–20.00	8.00–11.00	—	304
30305	0.12 max.	2.00	1.00	0.04	0.03	17.00–19.00	10.00–13.00	—	305
30309	0.20 max.	2.00	1.00	0.04	0.03	22.00–24.00	12.00–15.00	—	309
30310	0.25 max.	2.00	1.50	0.04	0.03	24.00–26.00	19.00–22.00	—	310
30316	0.08 max.	2.00	1.00	0.04	0.03	16.00–18.00	10.00–14.00	Mo 2.00–3.00	316
30317	0.08 max.	2.00	1.00	0.04	0.03	18.00–20.00	11.00–15.00	Mo 3.00–4.00	317
30321	0.08 max.	2.50	1.50	0.04	0.03	17.00–19.00	8.00–12.00	min. Ti 5 × C	321
30325	0.25 max.	0.60–0.90	1.00–2.00	—	—	7.00–10.00	19.00–23.00	Cu 1.00–1.50	325
30347	0.08 max.	2.50	1.50	0.04	0.03	17.00–19.00	9.00–13.00	min. Cb 10 × C	347

TABLE 2—*Wrought Stainless Chromium Irons and Steels*

SAE Number[a]	CHEMICAL COMPOSITION LIMITS, %								AISI TYPE[a]
	C	Max. Mn	Max. Si	Max. P	Max. S	Cr range	Ni range	Other elements	
51410	0.15 max.	1.00	1.00	0.04	0.03	11.50–13.50	—	—	410
51414	0.08–0.15	1.00	1.00	0.04	0.03	11.50–13.50	1.25–2.50	—	414
51416F	0.15 max.	1.25	1.00	—	—	12.00–14.00	—	P, S, Se min. 0.07 Zr, Mo max. 0.60	416
51420	0.30–0.40	1.00	1.00	0.04	0.03	12.00–14.00	—	—	420
51420F	0.30–0.40	1.25	1.00	—	—	12.00–14.00	—	P, S, Se min. 0.07 Zr, Mo max. 0.60	—
51430	0.12 max.	1.00	1.00	0.04	0.03	14.00–18.00	—	—	430
51430F	0.12 max.	1.25	1.00	—	—	14.00–18.00	—	P, S, Se min. 0.07 Zr, Mo max. 0.60	—
51431	0.20 max.	1.00	1.00	0.04	0.03	15.00–17.00	1.25–2.50	—	431
51440A	0.60–0.75	1.00	1.00	0.04	0.03	16.00–18.00	—	max. Mo 0.75	440A
51440B	0.75–0.95	1.00	1.00	0.04	0.03	16.00–18.00	—	max. Mo 0.75	440B
51440C	0.95–1.20	1.00	1.00	0.04	0.03	16.00–18.00	—	max. Mo 0.75	440C
51440F	0.95–1.20	1.25	1.00	—	—	16.00–18.00	—	P, S, Se min. 0.07 Zr, Mo max. 0.75	—
51442	0.20 max.	1.00	1.00	0.04	0.035	18.00–23.00	—	—	442
51446	0.25 max.	1.00	1.00	0.04	0.03	23.00–27.00	1.00 max.	—	446
51501	Over 0.10	1.00	1.00	0.04	0.03	4.00– 6.00	—	—	501

[a] Suffix F is used to denote a free-machining steel. Suffixes A, B, and C are used to denote three types of steel differing only in carbon content.

Methods of Sampling Steel

SAE General Information

Report of Iron and Steel Division approved January 1912 and last revised by Iron and Steel Technical Committee January 1950.

Definitions—*Ladle analysis* is the term applied to the average chemical composition of a heat or blow of steel before it is poured into the ingot molds. It is determined by the analysis of one or more samples taken during the pouring of the first or middle part of the heat or blow from the teeming ladle into the molds.

Ladle sampling is the common practice in most steel melting operations of obtaining more than one ladle test sample from each heat or blow; often three or more are taken representing the first, middle, and last portions of the heat or blow. Drillings taken from the first sample or middle sample are used in determining the ladle analysis because experience has shown that these locations most closely represent the chemical analysis of the entire heat or blow. The additional samples are used for survey of uniformity and for control purposes.

Check analysis, as used in the steel industry, means an analysis of the metal after it has been rolled or forged into semi-finished or finished forms, and is either for the purpose of verifying the average composition of a heat, blow, or lot as represented by the ladle analysis, or to determine variations in the composition of a heat, blow, or lot. It is not used, as the term might imply, for a duplicate determination made to confirm a previous result. The results of analyses representing different locations in the same piece or taken from different pieces of a lot may differ from each other and from the ladle analysis due to segregation.

Segregation is the result of that natural phenomenon in the solidification of a steel ingot in which various components of the steel having the lowest freezing points are concentrated in parts of the ingot last to solidify. This concentration at different locations results in such a distribution of elements in the ingot that certain areas contain more, while others contain less, of a given element than the average composition of the ingot as a whole.

Segregation in varying degrees is found in all types of steel ingots. The principal factors affecting the amount of segregation are the type and composition of steel, the casting temperature, the ingot shape and size, and the inherent segregating characteristics of the elements being considered.

Rimmed or capped steels are characterized by a lack of uniformity in their chemical composition, especially for the elements carbon, phosphorus, and sulfur, and for this reason check analysis is not considered appropriate for these elements unless misapplication is clearly indicated.

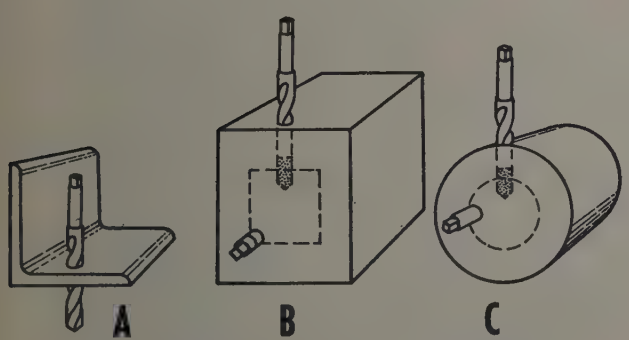


FIG. 1—LOCATION OF SAMPLES FOR CHECK ANALYSIS

In all types of steel, because of the degree to which phosphorus and sulfur tend to segregate, check analysis for these elements is equally inappropriate for rephosphorized or resulphurized steels unless indications of misapplication clearly exist.

The effect of segregation makes the ladle analysis more representative of the average composition of a melt of steel than the analysis of a single sample from the finished material. However check analyses of properly located samples will afford a reasonable comparison with the ladle analysis if taken from a sufficient number of pieces of the finished material to constitute a fair average.

Methods of Sampling for Check Analysis—Each heat or blow of steel in a lot or shipment is considered separately. To indicate adequately the representative composition of a heat, blow, or lot, samples selected to represent the melt as fairly as possible are taken from a minimum number of pieces as follows:

Four pieces for lots up to 15 tons, inclusive
Six pieces for lots over 15 tons.

If the number of pieces in a melt is less than the number of samples specified above, one sample shall be taken from each piece.

Location of Samples—*Large Sections*—For large sections including blooms, billets, slabs, rounds, squares, shapes, and others, samples shall be taken at any point midway between the outside and the center of the piece by drilling parallel to the axis. In cases where this is not practicable, the piece shall be drilled on the side (Figs. 1B and 1C), but the drillings shall not be collected until they represent the portion midway between the outside and the center. The tension test specimen may be used for sampling if it conforms to the above conditions.

Bored Forgings—For bored forgings, samples shall be taken midway between the inner and outer surface of the wall.

Methods of Sampling—*Thin Material*—For thin material or material of small cross-section such as plates, shapes, bars whose cross-sectional area does not exceed 0.75 sq in., and others, the method described above for large sections is not applicable and the sample shall be taken by machining off the entire cross-section, or if this is not possible, by drilling entirely through the material at a point midway between the outside and the center (Fig. 1A).

Sheets Rolled Longitudinally—For sheets rolled from slabs or bars longitudinally, the specimen for sampling shall be cut 2 in. in width and across the full width of the sheet as rolled. The specimen shall be cleaned by pickling or light grinding and then folded once or more by bringing the ends together and closing the bend. The sample for analysis shall be taken in the middle of this length by milling the inside sheared edges or drilling entirely through from the flat surface. Sampling by milling is preferable. For sheets of a light gage, several specimens may be taken and stacked together before folding.

Sheets Rolled Transversely—For sheets rolled from slabs or bars transversely, the specimen shall be cut from the side of the sheet, halfway between the middle and end as rolled 2 in. in width and 18 in. in length. If the sheet is No. 20 gage (24 oz per sq ft or 0.0359 in. thick) or lighter, the specimen shall be cut from the full length of the sheet as rolled. The specimen selected shall be cleaned by pickling or grinding and then folded

once or more by bringing the ends together and closing the bend. The sample for analysis shall be taken in the middle of this length by milling the inside sheared edges or drilling entirely through from the flat surface. Sampling by milling is preferable.

Sheets Not of the Full Size Rolled—Sheets cut from larger sheets and not of the full size rolled shall be sampled by milling or drilling the sheet in a sufficient number of places so that the sample is representative of the entire sheet. The sampling may be facilitated by folding the sheet both ways.

Preparation of Samples—Steel subjected to check analysis should be in the condition as received from the steel producer because if it has been subjected to subsequent heating operations it may not yield analytical results which properly represent its original composition.

Drillings or chips are taken without the application of water, oil, or other lubricant, and must be free from scale, grease, dirt, or other foreign substances. They should not be over-heated during cutting to the extent of causing decarburization. Chips must be well mixed, and those too coarse to pass a No. 10 (2000 microns) sieve or too fine to remain on a No. 30 (590 microns) sieve are not suitable for proper analysis. Sieve size numbers are ASTM designations.

When chips are taken by drilling, for pieces having a cross-sectional area up to 16 sq in., inclusive, the diameter of the drill is approximately ½ in.; for steel over 16 sq in. cross-sectional area, the diameter of the drill is approximately 1 in. Each sample commonly consists of not less than 2 oz of drillings.

In referring samples to other analysts for check analyses, pieces of the original full-size section, when possible, should be submitted rather than cuttings unless the latter are specifically requested.

Tentative Permissible Variations from Specified Chemical Ranges and Limits for Steels

SAE Standard

From report of Iron and Steel Division approved January 1942 and last revised by Iron and Steel Technical Committee January 1949.

Check analysis is applicable where a high degree of uniformity in composition is essential—for example, material that is to be heat-treated. Individual determinations may vary from the specified ranges or limits to the extent shown in Tables 1 and 4, but the several determinations of a single element in any one melt may not vary both above and below the specified range.

In the carbon-steel series, rimming steel is sometimes specified or required because of the physical characteristics inherent in that type of steel. In these applications, check-analysis results are not essential as a measure of the desired properties. Rimming steel and capped steel are characterized by a lack of homogeneity in their chemical composition, especially for the elements carbon, phosphorus, and sulfur. Therefore, check analysis is not applicable for elements other than manganese and copper.

Rephosphorized steel is not subject to check analysis for phosphorus, and resulfurized steel is not subject to check analysis for sulfur unless misapplication is clearly indicated.

(*Tables 2–4 on next page.*)

TABLE 1—*Permissible Variations from Specified Chemical Ranges and Limits for Open-Hearth and Acid Bessemer Carbon Steel in Hot-Rolled and Cold-Finished Bars and Semi-Finished for Forging to 100 Square Inches Inclusive and Seamless Welded Tubing*

ELEMENT	LIMIT OR MAXIMUM OF SPECIFIED RANGE, %	VARIATION, %, OVER THE MAXIMUM LIMIT OR UNDER THE MINIMUM LIMIT
Carbon	to 0.25 inclusive	0.02
	over 0.25 to 0.55 inclusive	0.03
	over 0.55	0.04
Manganese	to 0.90 inclusive	0.03
	over 0.90 to 1.65 inclusive	0.06
Phosphorus[a]	open-hearth steel, to 0.05 inclusive	0.008
	bessemer steel, to 0.12 inclusive	0.01
Sulfur[a]	to 0.06 inclusive	0.008
Silicon	to 0.35 inclusive	0.02
	over 0.35 to 0.60 inclusive	0.05
Copper[b]	for copper steel	0.02

[a] Over maximum, only.
[b] Under minimum, only.

TABLE 2—*Permissible Variations from Specified Chemical Ranges and Limits for Basic Open-Hearth and Acid Bessemer Carbon Steel Wire Rods*

ELEMENT	LIMIT OR MAXIMUM OF SPECIFIED RANGE, %	VARIATION, %, OVER THE MAXIMUM LIMIT OR UNDER THE MINIMUM LIMIT
Carbon	to 0.30 inclusive	0.01
	over 0.30 to 0.75 inclusive	0.01
	over 0.75	0.02
Manganese	to 0.90 inclusive	0.02
	over 0.90 to 1.65 inclusive	0.03
Phosphorus[a]	open-hearth steel, to 0.05 inclusive	0.005
	bessemer steel, to 0.12 inclusive	0.01
Sulfur[a]	to 0.06 inclusive	0.005
Silicon	to 0.35 inclusive	0.02
	over 0.35 to 0.60 inclusive	0.05
Copper[b]	for copper steel	0.02

[a] Over maximum, only.
[b] Under minimum, only.

TABLE 3—*Permissible Variations from Specified Chemical Ranges and Limits for Basic Open-Hearth and Acid Bessemer Carbon-Steel Structural Shapes and Plates, Sheet, Strip, and Welded Tubing*

ELEMENT	LIMIT OR MAXIMUM OF SPECIFIED ELEMENT, %	VARIATION OVER THE MAXIMUM LIMIT OR UNDER THE MINIMUM LIMIT	
		Under Minimum Limit	Over Maximum Limit
Carbon	to 0.15 inclusive	0.02	0.03
	over 0.15 to 0.40 inclusive	0.03	0.04
	over 0.40 to 0.80 inclusive	0.03	0.05
	over 0.80	0.03	0.06
Manganese	to 0.60 inclusive	0.03	0.03
	over 0.60 to 1.15 inclusive	0.04	0.04
	over 1.15 to 1.65 inclusive	0.05	0.05
Phosphorus	—	—	0.01
Sulfur	—	—	0.01
Silicon	to 0.30 inclusive	0.02	0.03
	over 0.30 to 0.60	0.05	0.05
Copper	—	0.02	—

TABLE 4[a]—*Permissible Variations from Specified Chemical Ranges and Limits for Basic Open-Hearth and Electric-Furnace Alloy Steels and Electric-Furnace Carbon Steels in All Hot-Rolled and Cold-Finished Sizes*

ELEMENT	LIMIT OR MAXIMUM OF SPECIFIED RANGE, %	VARIATION BY SIZE RANGES, %, OVER MAXIMUM LIMIT OR UNDER MINIMUM LIMIT			
		100 sq. in. or less	Over 100 to 200 sq in.	Over 200 to 400 sq in.	Over 400 sq in.
Carbon	to 0.30 inclusive	0.01	0.02	0.03	0.04
	over 0.30 to 0.75 inclusive	0.02	0.03	0.04	0.05
	over 0.75	0.03	0.04	0.05	0.06
Manganese	to 0.90 inclusive	0.03	0.04	0.05	0.06
	over 0.90 to 2.10 inclusive	0.04	0.05	0.06	0.07
Phosphorus[b]		0.005	0.01	0.01	0.01
Sulfur	to 0.060 inclusive	0.005	0.01	0.01	0.01
	over 0.060, not subject to check analysis				
Silicon	to 0.35 inclusive	0.02	0.02	0.03	0.04
	over 0.35 to 2.20 inclusive	0.05	0.06	0.06	0.07
Nickel	to 1.00 inclusive	0.03	0.03	0.03	0.03
	over 1.00 to 2.00 inclusive	0.05	0.05	0.05	0.05
	over 2.00 to 5.30 inclusive	0.07	0.07	0.07	0.07
	over 5.30	0.10	0.10	0.10	0.10
Chromium	to 0.90 inclusive	0.03	0.04	0.04	0.05
	over 0.90 to 2.10 inclusive	0.05	0.06	0.06	0.07
	over 2.10 to 3.99	0.10	0.10	0.12	0.14
Molybdenum	to 0.20 inclusive	0.01	0.01	0.02	0.03
	over 0.20 to 0.40 inclusive	0.02	0.03	0.03	0.04
	over 0.40 to 1.00 inclusive	0.03	0.04	0.05	0.06
Tungsten	to 1.00 inclusive	0.04	0.05	0.05	0.06
	over 1.00 to 4.00 inclusive	0.08	0.09	0.10	0.12
Vanadium	to 0.10 inclusive	0.01	0.01	0.01	0.01
	over 0.10 to 0.25 inclusive	0.02	0.02	0.02	0.02
	over 0.25 to 0.50 inclusive	0.03	0.03	0.03	0.03
	Minimum value only specified; check under specification.	0.01	0.01	0.01	0.01
Aluminum	to 1.50 inclusive	0.10	0.10	0.10	0.10

[a] Conforms with Table 4, Section 10 of AISI Steel Products Manual, July 1947.
[b] Over maximum, only.

High-Strength, Low-Alloy Steel, SAE 950

SAE Recommended Practice

Report of Iron and Steel Technical Committee approved January 1947 and last revised January 1949.

High-strength, low-alloy steel represents a specific type of steel in which enhanced mechanical properties and, in most cases, good resistance to atmospheric corrosion are obtained by the addition of moderate amounts of one or more alloying elements other than carbon.

Steels of this type are normally furnished in the hot-rolled or annealed condition to minimum mechanical properties. They are not intended for quenching and tempering. The user should not subject them to such treatment without assuming responsibility for the ensuing mechanical properties. Where these steels are used for fabrication by welding, no pre-heat or post-heat is required. In certain complex structures, stress relieving may be desirable. These steels may be obtained in any of the standard shapes or forms normally available in carbon steel.

TABLE 1—*Minimum Properties of Steel as Furnished by the Mill*

PROPERTY	THICKNESS OR DIAMETER, IN.				
	Up to 0.0709 inclusive	0.0710 to 0.2299 inclusive	0.2300 to ½ inclusive	Over ½ to 1 inclusive	Over 1 to 2 inclusive
Minimum yield point[a], psi	50,000	50,000	50,000	47,000	45,000
Minimum tensile strength[a], psi	70,000	70,000	70,000	67,000	65,000
Elongation[b] in 2 in., %	20	22[c,d]	22	22[e]	22[e]
Elongation[d] in 8 in.	—	—	1,500,000/tensile strength		
Bend test[f], 180 deg.	D = 1T	D = 1T	D = 1T	D = 2T	D = 3T

[a] For severe cold-forming operations requiring greater ductility, relaxation of the yield-point and tensile-strength requirements is commonly negotiated between producer and consumer.
[b] ASTM standard rectangular specimen, 2-in. gage length. (ASTM E 8).
[c] Minimum thickness for plates over 48 in. wide is 0.180 in.
[d] For plates, material 0.180 in. and heavier is customarily tested in 8-in. gage length using ASTM standard rectangular specimen subject to modification of ASTM A 242.
[e] For 0.505-in. diameter, use ASTM standard round specimen 2-in. gage length. (ASTM E 8.)
[f] Use ASTM A 242 bend test.

Application—These steels because of their enhanced strength, corrosion- and erosion-resistance, and their high strength-to-weight ratio and service life, are adapted particularly for use in mobile equipment and other structures where substantial weight savings are generally desirable. Typical applications are automotive bumper face bars, truck bodies, frames and structural members, scrapers, dump wagons, cranes, shovels, booms, chutes, conveyors, railroad and industrial cars.

Qualification Tests—At the option of the purchaser of a new or modified grade or radically different range of thickness, samples from one to three mill heats may be initially supplied for qualification tests for resistance welding, metallic arc welding, and for notched-bar impact properties of the particular grade or thickness range to be furnished. (The qualification is for information as to these and other desired properties and their variance from mill heat to mill heat.)

Chemical Composition Limitations—The maximum limits of the several elements are to be as given in Table 2 unless otherwise negotiated between producer and consumer.

Tolerances—The standard manufacturing tolerances for dimensions shall apply to the respective commodities procured under this specification. (Tolerances for carbon steel are given in the AISI Steel Products Manual; see Section 4 for structural shapes, Section 6 for plates, Section 8 for bars, Section 11 for sheets, Section 12 for hot-rolled strip, and Section 13 for cold-rolled strip.)

TABLE 2—*Chemical Composition Limits*

ELEMENT	CHEMICAL LIMIT	REMARKS
Carbon Manganese	0.12 max. 1.00 max.	For resistance welding.
Carbon Manganese	0.20 max. 1.25 max.	For other-than-resistance welding and non-welded applications.
Sulfur	0.050 max.	——
Phosphorus	0.150 max.	Phosphorus is beneficial as a strengthener and improves corrosion resistance, but it should be considered in conjunction with other elements in resistance welding applications wherein satisfactory low-temperature properties are required. To avoid excessive brittleness, severely cold-formed high-phosphorus material should be stress relieved.
Silicon	0.90 max.	Silicon is a strengthening element, but must be considered in connection with other elements and their effect on resistance welding.
Copper	—	Where copper exceeds 0.70% unless adjustments are made in composition, the phenomenon of precipitation hardening in heating should be given due consideration.
Other alloying elements	—	The choice of, and limits for alloying elements other than those mentioned necessary to attain required mechanical properties, are commonly negotiated between producer and consumer. The type of alloy combination should not be changed without the knowledge and consent of the purchaser and in accordance with the requirements implied by the above qualification tests.

Carbon and Alloy Steels

SAE General Information

Report of the Iron and Steel Technical Committee approved February 1948 and last revised January 1951

The conception that all steels are the same except for chemical constituents is false and misleading. Carbon steels may be produced with chemical composition (carbon, manganese, phosphorus, sulfur, and silicon) within the specified limits of a given grade and still have characteristics that are widely dissimilar. Each grade and quality variation thereof has a proper and useful place, depending upon the end products to be made and the methods of fabrication.

In all phases of steel production, various practices are employed which determine the quality and types of the finished material. The diversity of steel requirements necessitates a differentiation in grades and qualities and governs the practices and precautions required in steel making.

Quality Classifications—Technically, quality as the term relates to steel products may be indicative of many conditions such as the degree of internal soundness, relative uniformity of composition, relative freedom from injurious surface imperfections, and finish. Steel quality also relates to general suitability for particular applications.

As a result of these variables, *carbon steel* may be obtained only in a number of *fundamental* qualities, listed on the next page, depending upon the product. Superimposed upon some of those qualities may be such requirements as Limited Austenitic Grain Size, Specified Discard Macroetch Test, Special Heat-Treatment, Maximum Incidental Alloy Elements, Restrictive Ladle Analysis, Restrictive Check Analysis, and Nonmetallic Inclusions.

Also, as a result of these variables, *alloy steels* may be obtained in *special* qualities, some of which are listed on the next page. Superimposed upon some of these qualities may be such requirements as Extensometer Test, Fracture Test, Impact Test, Macroetch Test, Nonmetallic Inclusion Test, Special Hardenability Test, and Grain-Size Test.

For complete descriptions of the fundamental qualities and the supplementary restrictions of carbon steels and of the special qualities and supplementary restrictions of alloy steels, reference should be made to the latest applicable AISI Steel Products Manual Section. Manual numbers, titles, and latest revision dates are listed at the end of this SAE General Information Report.

Types of Steel—In most steelmaking processes, the primary reaction is the combination of carbon and oxygen to form a gas. If the oxygen available for this reaction is not removed prior to or during casting (by the addition of silicon or some other deoxidizer), the gaseous products continue to evolve during solidification. The amount of gas evolved during solidification determines the type of steel. If no gas is evolved, the steel is termed *killed* because it lies quietly in the molds. Increasing degrees of gas evolution result in *semi-killed*, *capped*, or *rimmed* steel.

Killed steels are characterized by a relatively high degree of uniformity of composition and properties. During the solidification of killed steel, there is practically no gas evolution. Composition is more uniform than that of the other types, although killed steel ingots also have some variations in composition from surface to center and bottom to top.

There are very few compositions of steel which cannot be killed provided that sufficient deoxidizing elements may be added to inhibit gas formation. Killed steel products, because of their greater uniformity in chemical composition and properties, are recommended for forging, piercing, carburizing, and heat-treating applications.

Rimmed steels are characterized by marked differences in composition across the section and from top to bottom of the ingot with respect to carbon, phosphorus, sulfur, and nonmetallic compounds. The typical structure of rimmed steel results from a marked gas evolution during solidification of the outer rim. Satisfactory rimmed steels do not retain any significant percentages of highly oxidizable elements such as aluminum, titanium, or silicon. Carbon content of this type steel is normally less than 0.25%, and the manganese content is normally under 0.60%. Rimmed steel products, because of their chemical compositions and their surface and other characteristics, may be used advantageously for the manufacture of finished articles involving cold bending, cold forming, cold heading, or deep-drawing operations.

Semi-killed steels are characterized by variable degrees of uniformity in composition and have properties intermediate between those of killed and rimmed steels. They are produced for applications such as structural parts and noncritical forgings or heat-treated parts, in which the specific properties and characteristics of killed or rimmed steels are not required.

Capped steels have characteristics similar to those of rimmed steels but to a degree intermediate between those of rimmed and semi-killed steels. Capped steel products, because of their chemical composition, surface, and other characteristics may be used to advantage when the material is to withstand cold bending, cold forming, or cold heading.

Commonly Specified Elements—The effect of a single commonly specified element (carbon, manganese, phosphorus, sulfur, silicon, or copper) on steelmaking practice and carbon-steel properties is dependent upon the effect of other elements. These interrelations, frequently of a complex nature, should be considered when evaluating a change in specified composition. It should be noted also that as the number of elements specified increases, and as restrictive repuirements increase, availability decreases, to the ultimate end that special heats become a necessity and material must be ordered in heat lots.

Carbon—The amount of carbon required in the finished steel limits the type of steel that can be made. As the carbon content of rimmed steels increases, surface quality becomes impaired. Killed steels by comparison have poorer surfaces in the lower carbon grades. Carbon has a moderate tendency to segregate within the ingot, and because of its major effect on properties, carbon segregation is frequently of more significant importance than the segregation of other elements. It is the principal hardening element in all steel. Tensile strength in the as-rolled condition increases as the carbon increases up to about 0.85% carbon. Ductility and weldability decrease with increasing carbon.

Manganese has a lesser tendency to segregate within the ingot than any of the common elements. Steels above 0.60% manganese can not be readily rimmed.

Manganese is beneficial to surface quality in all carbon ranges (with the exception of extremely low-carbon rimmed steels) and

Fundamental Qualities of Carbon Steels and Special Qualities of Alloy Steels

Carbon Steels

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Forging Quality	
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Cold-Rolled Sheets	
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Porcelain-Enameling Sheets	
Commercial Quality	
Drawing Quality	
Long-Terne Sheets	
Commercial Quality	
Drawing Quality	
Galvanized Sheets	
Commercial Quality	
Drawing Quality	
Hot-Rolled Strip	12
Commercial Quality	
Drawing Quality	
Physical Quality	
Cold-Rolled Strip	13
Specific quality descriptions are not provided in cold-rolled strip, since this product is largely produced for specific end use. Descriptions of such features as temper, finish, and edges may be found by consulting AISI Manual Section 13, where typical illustrations of the forming characteristics of each temper are shown.	
Tin-Mill Products	14
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Alloy Steels

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Axle-Shaft Quality	
Bearing Quality	
Cold-Heading Quality	
Rifle-Barrel Quality, Gun Quality, Shell or Shot Quality	
Flat Steel Wire	17
Alloy-Steel Flat Wire Commodities	
Steel Tubular Products	18
Pressure Tubes	
Mechanical Tubing	
Aircraft or Magnetic-Particle-Inspection Tubing	
Alloy Steel Wire	28
Aircraft or Magnetic-Particle-Inspection Quality	
Bearing Quality	
Cold-Finished Alloy-Steel Bars	29
Aircraft or Magnetic-Particle-Inspection Quality	
Axle-Shaft Quality	
Bearing Quality	
Cold-Heading Quality	
Rifle-Barrel Quality, Gun Quality, Shell or Shot Quality	

is particularly beneficial in high-sulfur steels. It contributes to strength and hardness but to a lesser degree than does carbon, the amount of increase being dependent upon the carbon content. Increasing the manganese content decreases ductility and weldability but to a lesser extent than does carbon.

Phosphorus has a marked tendency to segregate within the ingot. In the acid open-hearth and acid Bessemer processes, this element is not normally removed in refining and necessitates higher permissible specification limits.

Phosphorus increases strength and hardness in the as-rolled condition approximately as much as carbon. In some types of steel, it results in a marked decrease in ductility and notched-bar impact toughness. This is particularly true in higher-carbon steels that are quenched and tempered. Phosphorus improves resistance to atmospheric corrosion, and in low-carbon steels it improves machinability.

Sulfur has a greater tendency to segregate within the ingot than any of the common elements. It is very detrimental to surface quality, particularly in low-carbon and low-manganese steels. Resulfurized steels are characterized by a greater amount of inclusions than equivalent grades of low-sulfur steel.

Sulfur over 0.070% decreases transverse ductility, hardenability, and notched-bar impact toughness but has only a slight effect on longitudinal properties or as-rolled hardness. It is beneficial to machinability, and the improvement in this characteristic is the only reason for adding sulfur to steel. Weldability decreases with increasing sulfur.

Silicon is one of the principal deoxidizers used in steelmaking, and therefore the amount of silicon present is related to the type of steel. Rimmed and capped steels contain no significant amounts of silicon. Semi-killed steels may contain moderate amounts of silicon, though there is a definite maximum amount that can be tolerated in such steels. Killed carbon steels may contain any amount of silicon up to 0.60% maximum.

Silicon is somewhat less effective than manganese in increasing as-rolled strength and hardness. It has only a slight tendency to segregate within the ingot. In low-carbon steels, silicon is usually detrimental to surface quality, and this condition is more pronounced in low-carbon resulfurized grades.

Copper has a moderate tendency to segregate within the ingot. Copper in appreciable amounts is detrimental to hot-working operations. It adversely affects forge welding, but it does not seriously affect arc or acetylene welding. Copper is detrimental to surface quality and exaggerates the surface defects inherent in resulfurized steels. It is, however, very beneficial to atmospheric corrosion resistance when present in amounts exceeding 0.20%.

AISI Steel Products Manuals—The American Iron and Steel Institute's technical committees cooperate with the SAE Iron and Steel Technical Committee on standardization of compositions and related data on steels used in the automotive industries. AISI publishes Steel Products Manual Sections and Contributions to the Metallurgy of Steel, which are listed following for the information of users of SAE steels and which may be obtained from the American Iron and Steel Institute, 350 Fifth Avenue, New York 1, N. Y.

STEEL PRODUCTS MANUAL SECTIONS

Section	*Title*	*Latest Revision as of January 1, 1951*
1	Pig Iron and Blast Furnace Ferroalloys	April 1949
2	Semifinished Carbon Steel Products for Forging	May 1949
3	Hot Rolled Steel for Projectile Bodies	Nov. 1950
4	Carbon Steel Structural Sections	Aug. 1949
5	Steel Sheet Piling	May 1949
6	Carbon Steel Plates and Rolled Floor Plates	Sept. 1949
7	Alloy Steel Plates	Oct. 1949
8	Hot Rolled Carbon Steel Bars	May 1949
9	Cold Finished Carbon Steel Bars	May 1949
10	Hot Rolled Alloy Steels	May 1949
11	Carbon Steel Sheets	Sept. 1949
12	Hot Rolled Carbon Steel Strip	Aug. 1949
13	Cold Rolled Carbon Steel Strip	Sept. 1949
14	Tin Mill Products	Aug. 1949
15	Hot Rolled Carbon Steel Wire Rods	June 1949
16	Carbon Steel Wire	July 1949
17	Flat Steel Wire[1]	Feb. 1942
18	Steel Tubular Products	Nov. 1949
19	Railway Track Materials	July 1949
20	Wrought Steel Wheels	Aug. 1949
21	Concrete Reinforcing Bars	April 1949
22	Forged Axles and Locomotive Forgings	July 1949
23	Tolerances for Alloy Steel Sheets and Strip	April 1949
24	Stainless and Heat Resisting Steels	April 1950
25	Tool Steel Tolerances	April 1949
26	Flat Rolled Electrical Steel	July 1949
27	Rail Steel	April 1949
28	Alloy Steel Wire	Aug. 1949
29	Cold Finished Alloy Steel Bars	May 1949

CONTRIBUTIONS TO THE METALLURGY OF STEEL

No.	*Title*	*Latest Revision*
11	Hardenability of Alloy Steels[2]	May 1949

[1] Out of print.
[2] Published jointly by AISI and SAE. SAE Special Publications Department at 29 West 39 Street, New York 18, N. Y. will supply copies of this publication, Special Publication SP-4, at $1.00 each to members, $2.00 to nonmembers.

General Characteristics and Heat-Treatments of Steels

SAE General Information

Report of Iron and Steel Division approved January 1912 and last revised by Iron and Steel Technical Committee January 1950

[*The accompanying data are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.*

SAE Steels should be purchased on the basis of requirements as to chemical composition, and the specifications provided herein should be used in the purchase of the grades and types of steel covered by each. Requirements as to physical properties have been omitted because the majority of steels for automotive purposes are either worked or given special heat-treatments by the purchaser.]

General Instructions—In applying the detail heat-treatments outlined herein, it is recommended that, in order to obtain uniform physical properties, the final quench be made from the lowest temperature that will develop the maximum physical properties, bearing in mind that with thin sections, lower temperatures will suffice than with thick sections.

Normalizing and Annealing—When using the lower-carbon steels, simple normalizing is often sufficient to place the steel in its best condition for machining and will lessen distortion in carburizing or hardening. In the medium- and higher-carbon steels, combined normalizing and annealing constitutes the best practice.

For unimportant parts, the normalizing may be omitted entirely or annealing practiced only when the steel is otherwise difficult to machine. Both processes are recommended in the accompanying heat-treatments as representing the best metallurgical practice.

The temperatures recommended for normalizing and annealing have been made indefinite in many instances because of the many different types of furnace used in various plants and the difference in results desired. In many annealing practices, these operations are performed to produce definite microstructures suitable for specific machining conditions. Many companies equipped with continuous furnaces have of necessity established their own standard heating and cooling cycles for their individual operations. The annealing processes in a car-type furnace for bar annealing would not be conducted in the same manner as in a furnace for annealing small parts, and the same ultimate annealed structure would not be the objective. This means that annealing is an individual problem in each plant and industry which should be worked out in accordance with the ultimate results desired and the conditions existing.

Case Hardening—The process of carburizing as considered in this report refers to the various dry or pack hardening methods as well as to the newer processes utilizing gases and molten baths as the carburizing media.

There are two methods of proceeding after carburizing: (1) quenching directly and (2) cooling slowly or box cooling.

The first method involves removal of the work from the furnace or from the carburizing box and quenching the parts while they are at or slightly below the carburizing temperature or by quenching from gas carburizing furnaces.

The second method allows the work to cool slowly without any quenching, in the box or container or in a cooling chamber provided in the furnace.

The relative value of these two methods is dependent upon the type of steel treated, the method of carburizing, the kind of furnace installation, and the physical results desired.

Tempering of parts after carburizing, cyaniding, and activated-bath treatments is sometimes omitted in commercial practice but is included in the accompanying recommendations as being in accord with good heat-treating practice.

Parts carburized in activated baths should be treated similarly to other carburized work and may be given any of the hardening treatments shown under the specific steels.

Characteristics of Plain Carbon Steels

Tables 1 and 2 list typical treatments for carburizing grades and heat-treating grades, respectively, of carbon steels.

SAE 1006 1008 1010 1015

These steels are the lowest-carbon steels of the plain-carbon type and are selected where cold formability is the primary requisite. They are produced both as rimmed and killed steels. Rimmed steel is used for sheet, strip, rod, and wire where excellent surface finish or good drawing qualities are required, such as body and fender stock, hoods, lamps, oil pans, and a multitude of deep-drawn and formed products. It is also used for cold heading wire for tacks and rivets and low-carbon wire products. Killed steel (usually aluminum killed or special killed) is used for difficult stampings or where non-aging properties are needed. Killed steels (usually silicon killed) should be used in preference to rimmed steel for forging or heat-treating applications.

These steels have relatively low tensile values and should not be selected where much strength is desired. Within the carbon range of the group, strength and hardness will increase with increase in carbon and with cold work, but such increases in strength are at the sacrifice of ductility or the ability to withstand cold deformation. Where cold-rolled strip is used, the proper temper designation should be specified to obtain the desired properties.

When under 0.15% carbon, the steels are susceptible to serious grain growth, causing brittleness, which may occur as the result of a combination of critical strain (from cold work) followed by heating to certain elevated temperatures. Consequently if cold-worked parts formed from these steels are to be later heated to temperatures in excess of 1100 F, the user should exercise care to avoid trouble from this cause. When this condition develops, it can be overcome by heating the parts to a temperature well in excess of the upper critical point, or at least 1750 F.

Steels in this group, being nearly pure iron or ferritic in structure, do not machine freely and should be avoided for cut screws and operations requiring broaching or smooth finish on turning. The machinability of bar, rod, and wire products is improved by cold drawing. All of the steels in this group are readily welded by any of the common commercial methods.

(*Continued on next page.*)

SAE 1016 1017 1018 1019 1020 1021 1022 1024 1025

Steels in this group, because of the carbon range covered, have increased strength and hardness and reduced cold formability compared to the lowest-carbon group. For heat-treating purposes, they are commonly known as carburizing or case-hardening grades. When uniform response to heat-treatment is required, or for forgings, killed steel is preferred; for other uses, semi-killed or rimmed steel may be indicated, depending on the combination of properties desired. Rimmed steels can ordinarily be supplied up to 0.25 carbon.

1026 1027 1030

Selection of one of these steels for carburizing applications depends on the nature of the part, the properties desired, and the processing practice preferred. Increase in carbon gives greater core hardness with a given quench, or permits the use of thicker sections. Increase in manganese improves the hardenability of both the core and case; in carbon steels this the only change in composition that will increase case hardenability. The higher manganese variants also machine much better. For carburizing applications, SAE 1016, 1018, and 1019 are widely used for thin sections or water-quenched parts. SAE 1022 and 1024 are used for heavier sections or where oil quenching is desired, and SAE 1024 is sometimes used for such parts as transmission and rear-axle gears. SAE 1027 is used for parts given a light case to obtain satisfactory core properties without drastic quenching. SAE 1025 and 1030, while not usually regarded as carburizing types, are sometimes used in this manner for larger sections or where greater core hardness is needed.

For cold-formed or headed parts, the lowest manganese grades (SAE 1017, 1020, and 1025) offer the best formability at their carbon level. SAE 1020 is used for fan blades and some frame members, and SAE 1020 and 1025 are widely used for low-strength bolts. The next-higher-manganese types (SAE 1018, 1021, and 1026) provide increased strength.

All of these steels may be readily welded or brazed by the common commercial methods. SAE 1020 is frequently used for welded tubing.

These steels are used for numerous forged parts, the lower-carbon grades where high strength is not essential. Forgings from the lower-carbon steels usually machine better in the as-forged condition without annealing or after normalizing.

SAE 1030 1033 1034 1035

These steels, of the medium-carbon type, are selected for uses where their higher mechanical properties are needed and are frequently further hardened and strengthened by heat-treatment or by cold work. These grades are ordinarily produced as killed steels.

1036 1038 1039 1040 1041 1042 1043 1045 1046 1049 1050

Steels in this group are suitable for a wide variety of automotive applications. Selection of the particular carbon and manganese level is governed by a number of factors. Increase in the mechanical properties required, in section thickness, or in depth of hardening ordinarily indicates either higher carbon or manganese or both. The heat-treating practice preferred, especially the quenching medium, also has a great effect on the steel selected. In general, any of the grades over 0.30 carbon may be selectively hardened by induction or flame methods if desired.

1052

The lower carbon and manganese steels in this group find wide usage for certain types of cold-formed parts. SAE 1030 is used for shift and brake levers, SAE 1034 and 1035 are used in the form of wire and rod for cold upsetting work such as bolts, and SAE 1038 for bolts and studs. In practically all cases, the parts cold formed from these steels are heat-treated prior to use. Stampings are usually limited to flat parts or simple bends. The higher-carbon SAE 1038, 1040, and 1042 are frequently cold drawn to specified physical properties for use without heat-treatment for some applications, such as cylinder-head studs.

All of these steels are used for forgings, the selection being governed by the section size and the physical properties desired after heat-treatment. Thus SAE 1030 and 1035 are used for shifter forks and many small forgings where moderate properties are desired, but the deeper-hardening SAE 1036 is used for more critical parts where a higher strength level and more uniformity is essential, such as some front-suspension parts. Forgings such as connecting rods, steering arms, truck front axles, axle shafts, and tractor wheels are commonly made from the SAE 1038 to 1045 group. Larger forgings at similar strength levels need more carbon and perhaps more manganese. Examples are crankshafts from SAE 1046 and 1052. These steels are also used for small forgings where high hardness after oil quenching is desired. Suitable heat-treatment is necessary on forgings from this group to provide machinability.

These steels are also widely used for parts machined from bar stock, the selection following an identical pattern to that described for forgings. They are used both with and without heat-treatment, depending on the application and the level of properties needed. As a class, they are considered good for normal machining operations. It is also possible to weld these steels by most commercial methods, but precautions should be taken to avoid cracking from too-rapid cooling.

SAE 1055 1060 1062 1064 1065 1066 1070

Steels in this group are of the high-carbon type, having more carbon than is required to achieve maximum as-quenched hardness. They are used principally for applications where the higher carbon is needed to improve wear characteristics for cutting edges, to make springs of various types, and for special purposes. Selection of a particular grade is affected by the nature of the part, its end use, and the manufacturing methods available.

1074 1078 1080 1085 1086 1090 1095

In general, cold-forming methods are not practical with this group of steels, being limited to flat stampings and springs coiled from small-diameter wire. Practically all parts from these steels are heat-treated before use, with some variations in heat-treating methods to obtain optimum properties for the particular application, except cutting edges for earthmoving equipment.

Typical uses in the spring industry include SAE 1065 for pretempered wire and SAE 1066 for cushion springs of hard-drawn wire. SAE 1064 may be used for small washers and thin stamped parts, SAE 1074 for light flat springs formed from annealed stock, and SAE 1080 and 1085 for thicker flat springs. SAE 1085 is also used for heavier coil springs. Valve-spring wire and music wire are special products.

Because of good wear properties when properly heat-

TABLE 1—*Typical Treatments for Carburizing Grades of Carbon Steels*

SAE Steels	NORMALIZING TEMPERATURE, F	CARBURIZING TEMPERATURE, F	COOLING METHOD	REHEAT TEMPERATURE, F	COOLING MEDIUM	SECOND REHEAT, F	COOLING MEDIUM	COOLING MEDIUM TEMPERATURE, F
1010, 1015	—	1650–1700	Water or brine	—	—	—	—	250–400
1016	—	1650–1700	Oil or water	1400–1450	Water or brine	—	—	250–400
1017, 1018	—	1650–1700	Cool slowly	1400–1450	Water or brine	—	—	250–400
1019	—	1650–1700	Cool slowly	1650–1700	Oil or water	1400–1450	Water or brine	250 400
1020	—	1500–1650[a]	Oil or water	—	—	—	—	Optional
1021, 1022	—	1350–1575[b]	Air or oil	—	—	—	—	Optional
1024	1650–1750[c]	1650–1700	Oil	—	—	—	—	250–400
	—	1350–1575[b]	Air or oil	—	—	—	—	Optional
1025, 1026	—	1650–1700	Water or brine	—	—	—	—	250–400
	—	1500–1650[a]	Oil or water	—	—	—	—	Optional
1027	—	1350–1575[b]	Air or oil	—	—	—	—	Optional
1030	—	1500–1650[a]	Oil or water	—	—	—	—	Optional
	—	1350–1575[b]	Air or oil	—	—	—	—	Optional
1111, 1112, 1113	—	1500–1650[a]	Oil or water	—	—	—	—	Optional
	—	1350–1575[b]	Air or oil	—	—	—	—	Optional
1109, 1114	—	1650–1700	Water or brine	—	—	—	—	250–400
1115	—	1650–1700	Oil or water	1400–1450	Water or brine	—	—	250–400
1116, 1117	—	1650–1700	Cool slowly	1400–1450	Water or brine	—	—	250–400
	—	1650–1700	Cool slowly	1650–1700	Oil or water	1400–1450	Water or brine	250–400
1118	—	1500–1650[a]	Oil or water	—	—	—	—	Optional
1119, 1120	—	1350–1575[b]	Air or oil	—	—	—	—	Optional
1126	—	1500–1650[a]	Oil or water	—	—	—	—	Optional
	—	1350–1575[b]	Air or oil	—	—	—	—	Optional

[a] This treatment is for activated or cyanide baths. Parts may be given refining heat as indicated for other heat-treating processes.
[b] This treatment is for carbonitriding atmospheres. Parts may be given refining treatments as indicated for other heat-treating processes.
[c] Normalizing temperatures at least 50 F above the carbonizing temperature are sometimes recommended where heat-treat distortion is of vital importance.

treated, the high-carbon steels find wide usage in the farm-implement industry. SAE 1070 has been used for plow beams, SAE 1074 for plow shares, and SAE 1078 for such parts as rake teeth, scrapers cultivator shovels, and plow shares. SAE 1085 has been used for scraper blades, discs, and spring-tooth harrows. SAE 1086 and 1090 find use as mower and binder sections, twine holders, and knotter discs.

Characteristics of Free-Cutting Carbon Steels

This class of steels is intended for those uses where easy machining is the primary requirement. They are characterized by a higher sulfur content than comparable carbon steels. This results in some sacrifice of cold-forming properties, weldability, and forging characteristics. In general, the uses are similar to those for carbon steels of similar carbon and manganese content.

Tables 1 and 2 list typical heat-treatments for carburizing and heat-treating grades, respectively, of these steels.

SAE 1111, 1112, 1113 These steels are commonly known as Bessemer screw stock and are considered the best machining steels available, machinability improving within the group as sulfur increases. They are used for a wide variety of machined parts. While of excellent strength in the cold-drawn condition, they have an unfavorable property of cold shortness and are not commonly used for vital parts. These steels may be cyanided or carburized, but when uniform response to heat treating is necessary, open-hearth steels are recommended.

SAE 1109, 1114, 1115, 1116, 1117, 1118, 1119, 1120, 1126 Steels in this group are used where a combination of good machinability and more uniform response to heat-treatment is needed. The lower-carbon varieties are used for small parts which are to be cyanided or carbonitrided. SAE 1116, 1117, 1118, and 1119 carry more manganese for better hardenability, permitting oil quenching after case-hardening heat-treatments in many instances. The higher-carbon SAE 1120 and 1126 provide more core hardness when this is needed.

TABLE 2—*Typical Treatments for Heat-Treating Grades of Carbon Steels*

SAE Steels	NORMALIZING TEMPERATURE, F	ANNEALING TEMPERATURE, F	HARDENING TEMPERATURE, F	QUENCHING MEDIUM	TEMPER[a]
1025 1030	—	—	1575–1650	Water or brine	To desired hardness
1033[b] 1034 1035	—	—	1525–1575	Oil or water	To desired hardness
1036	1600–1700	—	1525–1575	Oil or water	To desired hardness
	—	—	1525–1575	Oil or water	To desired hardness
1038 1039[b] 1040	1600–1700	—	1525–1575	Oil or water	To desired hardness
	—	—	1525–1575	Oil or water	To desired hardness
1041	1600–1700 and/or	1400–1500	1475–1550	Oil	To desired hardness
1042 1043[b] 1045[b] 1046[b] 1050[b]	1600–1700	—	1475–1550	Oil or water	To desired hardness
1052 1055	1550–1650 and/or	1400–1500	1475–1550	Oil	To desired hardness
1060 1062 1064 1065 1066 1070 1074	1550–1650 and/or	1400–1500	1475–1550	Oil	To desired hardness
1078	—	1400–1500[c]	1450–1500	Water or brine	To desired hardness
1080 1085 1086 1090	1550–1650 and/or	1400–1500[c]	1450–1500	Oil[d]	To desired hardness
1095	—	1400–1500[c]	1450–1500	Oil, water, or brine	To desired hardness
	—	1400–1500[c]	1500–1600	Oil	To desired hardness
1132 1137	1600–1700 and/or	1400–1500	1525–1575	Oil or water	To desired hardness
1138 1140	—	—	1500–1550	Oil or water	To desired hardness
	1600–1700	—	1500–1550	Oil or water	To desired hardness
1141 1144	—	1400–1500	1475–1550	Oil	To desired hardness
	1600–1700	1400–1500	1475–1550	Oil	To desired hardness
1145 1146 1151	—	—	1475–1550	Oil or water	To desired hardness
	1600–1700	—	1475–1550	Oil or water	To desired hardness

[a] Even where recommended draw temperatures are shown, the draw is not mandatory on many applications. Tempering is generally employed for a partial stress relief and improves resistance to cracking from grinding operations. Higher temperatures than those shown may be employed where the hardness specification on the finished parts permits.

[b] Commonly used on parts where induction hardening is employed. However, all steels from SAE 1030 up may have induction hardening applications.

[c] Spheroidal structures are often required on these high-carbon steels for machining purposes and should be cooled very slowly or be isothermally transformed to produce the desired structure.

[d] May be water or brine quenched by special techniques such as partial immersion or time quenched; otherwise they are subject to quench cracking.

(*Text continued on next page.*)

SAE 1132 1137 1138 1140 1141 1144 1145 1146 1151

This group of steels has characteristics comparable to carbon steels of the same carbon level, except for changes as noted previously.

They are widely used for parts where a large amount of machining is necessary, or where threads, splines, or other operations offer special tooling problems. SAE 1137, for example, is widely used for nuts and bolts and studs with machined threads. The higher-manganese SAE 1132, 1137, 1141, and 1144 offer greater hardenability, the higher-carbon types being suitable for oil quenching for many parts. All of these steels may be selectively hardened by induction or flame heating if desired.

Common Constructional Alloy Steels (Other Than Stainless and Austenitic)

By common custom a steel is considered to be an alloy steel when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese 1.65%, silicon 0.60%, copper 0.60%, or, steel for which definite range of chromium up to 3.99%, nickel, molybdenum, vanadium, or a specified minimum quantity of any of the following, or other useful elements, is implied or required: aluminum, boron, cobalt, columbium, titanium, tungsten, or zirconium.

The principal uses for alloying elements in the common constructional steels are (1) to overcome the effect of mass in hardening, permitting use of a slower quench than is obtained with water and thus avoiding excessive distortion and cracking, and (2) to a limited extent for obtaining some special qualities not possessed by a simple carbon steel of equivalent carbon content.

Alloy steels are generally not specified for use without appropriate heat-treatment. Some special properties which certain alloying elements impart are: retardation of transformation, lowering of transformation temperature, resistance to creep at elevated temperatures, retention of toughness at sub-zero temperature, resistance to wear, and effect on hardness and machinability. Other special properties may be imparted by the proper choice of alloying elements. Thus, when the proper percentage and type of alloying elements are chosen, a complicated part after being completely austenitized may be hardened by quenching at a temperature considerably below the austenitizing temperature, and thereby greatly reduce the usual distortion and residual stresses accompanying the quenching.

Alloy steels are usually made under the best practice which will yield fully killed steel in the ingot. Such practice generally assures uniformity of composition and hardenability.

The hardenability or response to heat-treatment is probably the most important criterion for the selection of steel. By the term *"hardenability"* is meant the property that determines the depth and distribution of hardness induced by quenching from above the transformation range. It is well known and easily proved that the surface hardness of all steels—including the common alloy steels—when quenched at the optimum speed for the particular composition, depends upon the carbon content *at the surface*. The optimum speed for the production of maximum hardness, however, may be greater than that produced by oil quenching, consequently hardenability as well as carbon may affect the surface hardness of medium-carbon oil-quenched alloy steels.

Decarburized, scale-coated, and overheated surfaces, or surfaces from which heat is abstracted at less than the critical speed, may not attain expected hardness. When a carbon content of 0.65% is reached, little more may be expected in terms of indentation hardness (Rockwell or Brinell), regardless of the quenching practice or the alloy content of the steel. Most of the physical properties such as tensile strength, hardness, and toughness are related to the thoroughness with which the transformation in hardening is effected.

By *"hardening"* it is implied that a different structure has been obtained than that originally existing in the piece. The hardest type of structure is martensite. The hardness of the 100%-martensitic structure depends wholly upon the carbon content. If the heat-treatment is such that a minimum of 90% martensite is produced in quenching, and such that the final hardness is produced with proper tempering, it may be expected that all the final physical properties commonly computed as tensile strength, yield strength, and fatigue strength will be dependent upon the surface and cross-sectional hardness.

If in commercial operations a high percentage of martensite is not obtained in quenching, a corresponding reduction in the final properties may be expected after the tempering operation.

During the 1940's, it was fairly well established that the physical properties obtainable in a given section of steel can be closely evaluated by the measure of hardenability attained in the particular section, irrespective of the steel composition. That is to say, many different steel compositions can be interchanged to obtain a similar range of physical properties in the finished part if these physical properties are properly ascertained by careful consideration of the hardenability test.

The end-quench hardenability test described in the SAE Recommended Practice on Method of Determining Hardenability, commonly called the Jominy test, has enabled the investigator to compare easily and certainly the characteristic hardenability of various types of steel composition, or steels of the same typical composition made by different practices. In other words, the end-quench hardenability test is a convenient summation of all the characteristics which determine the degree of a surface hardness and the depth of penetration of hardness in quenching. By tempering the end-quenched bar, the final hardness of the product after quenching and tempering may be predicted.

Properties such as ease of annealing, degree of hardening from cold working, ease of machining, and some other characteristics may be peculiar to either composition or heat-treatment or both. The choice of steel for a given application is more often dictated by the overall economic consideration than by any other factor.

In general, the common automotive alloy steels may be divided into two grades: (a) the low-carbon carburizing and (b) the higher-carbon directly hardenable grade.

Carburizing Grades of Alloy Steels

Properties of the Case—The properties of carburized and hardened cases depend upon the carbon and alloy content, the structure of the case, and the degree and distribution of residual stresses. The carbon content of the case depends upon the details of the carburizing process and the response of iron and the alloying elements present to carburization. The original carbon content of the steel has little or no effect upon the carbon content produced in the case. The hardenability of the case, therefore, depends upon the alloy content of the steel and the *final* carbon

content produced by carburizing, but not upon the *initial* carbon content of the steel.

With complete carbide solution, the effect of alloying elements upon the hardenability of the case will in general be the same as the effect of these elements upon the hardenability of the core. As an exception to this, any element which inhibits carburizing may reduce the hardenability of the case. It is also true that some elements which raise the hardenability of the core may tend to produce more retained austenite and consequently somewhat lower hardness in the case.

Alloy steels are frequently used for case hardening because the required surface hardness can be obtained by moderate speeds of quenching. This may mean less distortion than would be encountered with water quenching. It is usually desirable to select a steel which will attain a minimum surface hardness of 58 or 60 Rockwell C after carburizing and oil quenching. Where section sizes are large, a high-hardenability alloy steel may be necessary, while for medium and light sections, low-hardenability steels will suffice.

In general, the case-hardening alloy steels may be divided into two classes so far as the hardenability of the case is concerned. Only the general types of steel are given. As the original carbon content of the steel has no effect upon the carbon content of the case, the last two digits in the specification numbers are not meaningful so far as the case is concerned.

High-hardenability-case steels include SAE 2500, SAE 3300, SAE 4300, SAE 4800, and SAE 9300.

As these are high-alloy steels, both the case and the core have high hardenability. These types of steel are used particularly for carburized parts having thick sections, such as bevel drive pinions and heavy gears. Good case properties can be obtained by oil quenching. These steels are likely to have retained austenite in the case after carburizing and quenching; consequently special precautions or treatments, such as refrigeration, may be required.

Medium-hardenability-case steels include SAE 1300, SAE 2300, SAE 4000, SAE 4100, SAE 4600, SAE 5100, SAE 8600, and SAE 8700.

Their hardenability is intermediate between that of plain carbon steel and the higher-alloy carburizing steels just described. In general, these steels can be used for average-size case-hardened automotive parts such as gears, pinions, piston pins, ball studs, universal crosses, and crankshafts. Satisfactory case hardness should be produced in most cases by oil quenching.

Core Properties—The core properties of case hardened steels depend upon both carbon and alloy content of the steel. Each of the general types of alloy case-hardening steel is usually made with two or more carbon contents so as to produce different hardenability in the core.

The most desirable hardness for the core depends upon the design and functioning of the individual part. In general, where high compressive loads are encountered, relatively high core hardness is beneficial in supporting the case. Low core hardnesses may be desirable where great toughness is essential.

The case-hardening steels may be divided into three general classes depending upon hardenability of the core. (For hardenability of individual steels, see the SAE Standard on Hardenability Bands for H Steels.)

Due to the fact that H bands have not been worked out for all steels, it is impossible to give an accurate comparative rating of hardenability of all of the steels in any one group.

Low-hardenability-core steels include SAE 4017, SAE 4023, SAE 4024, SAE 4027,[1] SAE 4028,[1] SAE 4608, SAE 4615, SAE 4617,[1] SAE 8615,[1] and SAE 8617.[1]

Medium-hardenability-core steels include SAE 1320, SAE 2317, SAE 2512, SAE 2515,[1] SAE 3115, SAE 3120, SAE 4032, SAE 4119, SAE 4317, SAE 4620, SAE 4621, SAE 4812, SAE 4815,[1] SAE 5115, SAE 5120, SAE 8620, SAE 8622, SAE 8720, and SAE 9420.

High-hardenability-core steels include SAE 2517, SAE 3310, SAE 3316, SAE 4320, SAE 4817, SAE 4820, SAE 9310, SAE 9315, and SAE 9317.

Heat Treatments—In general, all of the alloy carburizing steels are made fine grain, and most are suitable for direct quenching from the carburizing temperature. Several other types of heat-treatment involving single and double quenching are also used for most of these steels. (See Table 3.)

Directly Hardenable Grades of Alloy Steels—These steels may be considered in five groups on the basis of approximate mean carbon content of the SAE specification. In general, the last two figures of the specification agree with the mean carbon content. Consequently the heading "0.30–0.37 Mean Carbon Content of SAE Specification" includes steels such as SAE 1330, SAE 3135, and SAE 4137.

Mean Carbon Content of SAE Specification	*Common Applications* (See also more detailed discussion below)
0.30–0.37%	Heat-treated parts requiring moderate strength and great toughness.
0.40–0.42%	Heat-treated parts requiring higher strength and good toughness.
0.45–0.50%	Heat-treated parts requiring fairly high hardness and strength with moderate toughness.
0.50–0.62%	Springs and hand tools.
1.02%	Ball and roller bearings.

It is necessary to deviate from the above plan in the classification of the carbon-molybdenum steels. When carbon-molybdenum steels are used, it is customary to specify higher carbon content for any given application than would be specified for other alloy steels, due to the low alloy content of these steels. For example, SAE 4063 is used for the same applications as SAE 4140, 4145, and 5150. Consequently in the following tables and discussion, the carbon-molybdenum steels have been shown in the groups where they belong on the basis of applications rather than carbon content.

For the present discussion, steels of each carbon content are divided into two or three groups on the basis of hardenability. Transformation ranges and consequently heat-treating practices vary somewhat with different alloying elements even though the hardenability is not changed.

0.30–0.37 Mean Carbon Content of SAE Specification—These steels are frequently used for water-quenched parts of moderate section size and for oil-quenched parts of small section size.

Typical applications of these steels are connecting rods, steering arms and steering knuckles, axle shafts, bolts, studs, screws, and other parts requiring strength and toughness where section size is small enough to permit obtaining the desired physical properties with the customary heat-treatment.

(*Text continued after Table 4.*)

[1] These are borderline cases which might be considered in the next higher hardenability group.

TABLE 3—*Typical Heat-Treatments for Carburizing Grades of Alloy Steels*

SAE Steels	ALTERNATE PRE-TREATMENTS		CYCLE ANNEAL[c]	CARBURIZING TEMPERATURE, F	COOLING METHOD	REHEAT TEMPERATURE, F	COOLING MEDIUM	TEMPERING[d] TEMPERATURE, F
	Normalize[a]	Normalize & Temper[b]						
1320	Yes	—	—	1650–1700	Quench in oil	1400–1450[e]	Oil	250–350
	Yes	—	—	1650–1700	Quench in oil	1475–1525[f]	Oil	250–350
	Yes	—	—	1650–1700	Cool slowly	1400–1450[e]	Oil	250–350
	Yes	—	—	1650–1700	Cool slowly	1500–1550[f]	Oil	250–350
	Yes	—	—	1650–1700	Quench in oil[g]	—	—	250–350
	Yes	—	—	1500–1650[h]	Quench in oil	—	—	250–350
2317	Yes	—	Yes	1650–1700	Quench in oil	1375–1425[e]	Oil	250–350
	Yes	—	Yes	1650–1700	Quench in oil	1450–1500[f]	Oil	250–350
	Yes	—	Yes	1650–1700	Cool slowly	1375–1425[e]	Oil	250–350
	Yes	—	Yes	1650–1700	Cool slowly	1475–1525[f]	Oil	250–350
	Yes	—	Yes	1650–1700	Quench in oil[g]	—	—	250–350
	Yes	—	Yes	1450–1650[h]	Quench in oil	—	—	250–350
2512, 2515, 2517	—	Yes	—	1650–1700	Cool slowly	1325–1375[e]	Oil	250–350
	—	Yes	—	1650–1700	Cool slowly	1425–1475[f]	Oil	250–350
3115, 3120	Yes	—	—	1650–1700	Quench in oil	1400–1450[e]	Oil	250–350
	Yes	—	—	1650–1700	Quench in oil	1475–1525[f]	Oil	250–350
	Yes	—	—	1650–1700	Cool slowly	1400–1450[e]	Oil	250–350
	Yes	—	—	1650–1700	Cool slowly	1500–1550[f]	Oil	250–350
	Yes	—	—	1650–1700	Quench in oil[g]	—	—	250–350
	Yes	—	—	1500–1650	Quench in oil[h]	—	—	250–350
3310, 3316	—	Yes	—	1650–1700	Quench in oil	1400–1450[e]	Oil	250–350
	—	Yes	—	1650–1700	Cool slowly	1475–1500[f]	Oil	250–350
4017, 4023, 4024, 4027, 4028, 4032	Yes	—	Yes	1650–1700	Quench in oil[g]	—	—	250–350
4119, 4125	Yes	—	—	1650–1700	Quench in oil[g]	—	—	250–350
4317, 4320	Yes	—	Yes	1650–1700	Quench in oil	1425–1475[e]	Oil	250–350
4608	Yes	—	Yes	1650–1700	Quench in oil	1475–1525[f]	Oil	250–350
4615, 4617	Yes	—	Yes	1650–1700	Cool slowly	1425–1475[e]	Oil	250–350
	Yes	—	Yes	1650–1700	Cool slowly	1475–1525[f]	Oil	250–350
4620, X4620, 4621	Yes	—	Yes	1650–1700	Quench in oil[g]	—	—	250–350
	Yes	—	—	1500–1650[h]	Quench in oil	—	—	250–350
4812, 4815, 4817, 4820	—	Yes	Yes	1650–1700	Quench in oil	1375–1425[e]	Oil	250–350
	—	Yes	Yes	1650–1700	Quench in oil	1450–1500[f]	Oil	250–350
	—	Yes	Yes	1650–1700	Cool slowly	1375–1425[e]	Oil	250–350
	—	Yes	Yes	1650–1700	Cool slowly	1450–1500[f]	Oil	250–350
	—	—	—	1650–1700	Quench in oil[g]	—	—	250–350
5115, 5120	Yes	—	—	1650–1700	Quench in oil	1425–1475[e]	Oil	250–350
	Yes	—	—	1650–1700	Quench in oil	1500–1550[f]	Oil	250–350
	Yes	—	—	1650–1700	Cool slowly	1425–1475[e]	Oil	250–350
	Yes	—	—	1650–1700	Cool slowly	1500–1550[f]	Oil	250–350
	Yes	—	—	1500–1650[h]	Quench in oil	—	—	250–350
8615	Yes	—	Yes	1650–1700	Quench in oil	1475–1525[e]	Oil	250–350
8617	Yes	—	Yes	1650–1700	Quench in oil	1525–1575[f]	Oil	250–350
8620	Yes	—	Yes	1650–1700	Cool slowly	1475–1525[e]	Oil	250–350
8622	Yes	—	Yes	1650–1700	Cool slowly	1525–1575[f]	Oil	250–350
8625	Yes	—	Yes	1650–1700	Quench in oil[g]	—	—	250–350
8720	Yes	—	Yes	1500–1650[h]	Quench in oil	—	—	250–350
9310, 9315, 9317	—	Yes	—	1650–1700	Quench in oil	1400–1450[e]	Oil	250–350
	—	Yes	—	1650–1700	Cool slowly	1500–1525	Oil	250–350

[a] Normalizing temperatures should be not less than 50 F higher than the carburizing temperature followed by aircooling.
[b] After normalizing, reheat to temperature of 1000 to 1200 F and hold approximately 4 hr.
[c] Where cycle annealing is desired, heat to normalizing temperature, hold for uniformity, cool rapidly to 1000-1250 F. Hold 1 to 3 hr., then aircool or furnace cool to obtain a structure suitable for machining and finish.
[d] Tempering treatment is optional. Tempering is generally employed for partial stress relief and improved resistance to cracking from grinding operations. Temperatures higher than those shown are used in some instances where application requires.
[e] This treatment is applicable when case hardness only is paramount.
[f] This treatment is applicable when higher core hardness is desired.
[g] This treatment is applicable to fine-grained steels only. When fine-grained steels are employed, a second reheat is often unnecessary.
[h] This treatment is for activated or cyanide baths, and parts may be given refining heats as indicated for other heat-treating processes.

TABLE 4—*Typical Heat-Treatments for Directly Hardenable Grades of Alloy Steels*

SAE Steels	NORMALIZING TEMPERATURE, F		ANNEALING TEMPERATURE, F	HARDENING TEMPERATURE, F	QUENCHING MEDIUM	TEMPER
1330	—	—	—	1525–1575	Water or oil	To desired hardness
	1600–1700	and/or	1500–1600	1525–1575	Water or oil	To desired hardness
1335 1340	—	—	—	1500–1550	Oil	To desired hardness
	1600–1700	and/or	1500–1600	1525–1575	Oil	To desired hardness
2330	—	—	—	1450–1500	Oil	To desired hardness
	1600–1700	and/or	1400–1500	1450–1500	Oil	To desired hardness
2340 2345	—	—	—	1425–1475	Oil	To desired hardness
	1600–1700	and/or	1400–1500	1425–1475	Oil	To desired hardness
3130	1600–1700	—	—	1500–1550	Water or oil	To desired hardness
3135 3140 3141	—	—	—	1500–1550	Oil	To desired hardness
	1600–1700	and/or	1450–1550	1500–1550	Oil	To desired hardness
3145 3150	—	—	—	1500–1550	Oil	To desired hardness
	1600–1700	and/or	1400–1500	1500–1550	Oil	To desired hardness
4037	—	—	1525–1575	1500–1575	Oil	Gears 350–450 F
4042	—	—	1525–1575	1500–1575	Oil	To desired hardness
4047 4053	—	—	1450–1550	1500–1575	Oil	To desired hardness
4063 4068	—	—	1450–1550	1475–1550	Oil	To desired hardness
4130	1600–1700	and/or	1450–1550	1600–1650	Water or oil	To desired hardness
4137 4140	1600–1700	and/or	1450–1550	1550–1600	Oil	To desired hardness
4145 4150	1600–1700	and/or	1450–1550	1500–1600	Oil	To desired hardness
4340	1600–1700	and temper	1100–1225	1475–1525	Oil	To desired hardness
4640	1600–1700	and/or	1450–1550	1450–1500	Oil	To desired hardness
	1600–1700	and/or	1450–1500	1450–1500	Oil	Gears 350–450 F
5045 5046	1600–1700	and/or	1450–1550	1475–1500	Oil	250–300 F
5130	1650–1750	and/or	1450–1550	1500–1550	Water or caustic solution	To desired hardness
5132	1650–1750	and/or	1450–1550	1500–1550	Water, caustic solution, or oil	To desired hardness
5135 5140 5145	1650–1750	and/or	1450–1550	1500–1550	Oil	To desired hardness
	1650–1750	and/or	1450–1550	1500–1550	Oil	Gears 350–400 F
5147 5150 5152	1650–1750	and/or	1450–1550	1475–1550	Oil	To desired hardness
	1650–1750	and/or	1450–1550	1475–1550	Oil	Gears 350–400 F
50100 51100 52100	—	—	1350–1450	1425–1475	Water	To desired hardness
	—	—	1350–1450	1500–1600	Oil	To desired hardness

(Continued on next page.)

TABLE 4 (Concluded)—*Typical Heat-Treatments for Directly Hardenable Grades of Alloy Steels*

SAE Steels	NORMALIZING TEMPERATURE, F		ANNEALING TEMPERATURE, F	HARDENING TEMPERATURE, F	QUENCHING MEDIUM	TEMPER
6150	1650–1750	and/or	1550–1650	1600–1650	Oil	To desired hardness
9254, 9255, 9260, 9261, 9262	—	—	—	1500–1650	Oil	To desired hardness
8627, 8630, 8632	1600–1700	and/or	1450–1550	1550–1650	Water or oil	To desired hardness
8635, 8637, 8640, 8641	1600–1700	and/or	1450–1550	1525–1575	Oil	To desired hardness
8642, 8645, 8647, 8650, 8653	1600–1700	and/or	1450–1550	1500–1550	Oil	To desired hardness
8655, 8660	1650–1750	and/or	1450–1550	1475–1550	Oil	To desired hardness
8735, 8740	1600–1700	and/or	1450–1550	1525–1575	Oil	To desired hardness
8745, 8750	1600–1700	and/or	1450–1550	1500–1550	Oil	To desired hardness
9437, 9440	1600–1700	and/or	1450–1550	1550–1600	Oil	To desired hardness
9442, 9445, 9747	1600–1700	and/or	1450–1550	1500–1600	Oil	To desired hardness
9840	1600–1700	and/or	1450–1550	1500–1550	Oil	To desired hardness
9845, 9850	1600–1700	and/or	1450–1550	1500–1550	Oil	To desired hardness

Steels falling in this classification may be subdivided into two groups on the basis of hardenability:

Low-hardenability steels in the 0.30–0.37-mean-carbon-content classification include SAE 1330, SAE 1335, SAE 4037, SAE 4042, SAE 4130, SAE 5130, SAE 5132, and SAE 8630.

Medium-hardenability steels in the 0.30–0.37-mean-carbon-content classification include SAE 2330, SAE 3130, SAE 3135, SAE 4137, SAE 5135, SAE 8632, SAE 8635, SAE 8637, SAE 8735, and SAE 9437.

0.40–0.42 Mean Carbon Content of SAE Specification—In general, these steels are used for medium- and large-size parts requiring a high degree of strength and toughness. The choice of the proper steel depends upon the section size and the mechanical properties which must be produced. The low- and medium-hardenability steels are used for average-size automotive parts such as steering knuckles, axle shafts, and propeller shafts. The high-hardenability steels are used particularly for large axles and shafts and for large aircraft parts.

These steels are usually considered as oil-quenching steels, although some large parts made of the low- and medium-hardenability classifications may be quenched in water under properly controlled conditions.

These steels may be roughly divided into three groups on the basis of hardenability:

Low-hardenability steels in the 0.40–0.42-mean-carbon-content classification include SAE 1340, SAE 4047, SAE 5140, and SAE 9440.

Medium-hardenability steels in the 0.40–0.42-mean-carbon-content classification include SAE 2340, SAE 3140, SAE 3141, SAE 4053, SAE 4063, SAE 4140, SAE 4640, SAE 8640, SAE 8641, SAE 8642, SAE 8740, SAE 8742, and SAE 9442.

High-hardenability steels in the 0.40–0.42-mean-carbon-con-

tent classification include SAE 4340 and SAE 9840.

0.45–0.50 Mean Carbon Content of SAE Specification—These steels are used primarily for gears and other parts requiring fairly high hardness as well as strength and toughness. Such parts are usually oil quenched, and a minimum of 90% martensite in the as-quenched condition is desirable.

Low-hardenability steels in the 0.45–0.50-mean-carbon-content classification include SAE 5045, SAE 5046, SAE 5145, SAE 9747, and SAE 9763.

Medium-hardenability steels in the 0.45–0.50-mean-carbon-content classification include SAE 2345, SAE 3145, SAE 3150, SAE 4145, SAE 5147, SAE 5150, SAE 8645, SAE 8647, SAE 8650, SAE 8745, SAE 8747, SAE 8750, SAE 9445, and SAE 9845.

High-hardenability steels in the 0.45–0.50-mean-carbon-content classification include SAE 4150 and SAE 9850.

0.50–0.62 Mean Carbon Content of SAE Specification—These steels are used primarily for springs and hand tools. The hardenability necessary depends upon the thickness of the material and the quenching practice.

Medium-hardenability steels in the 0.50–0.62-mean-carbon-content classification include SAE 4169, SAE 5150, SAE 5152, SAE 6150, SAE 8650, SAE 9254, SAE 9255, SAE 9260, and SAE 9261.

High-hardenability steels in the 0.50–0.62-mean-carbon-content classification include SAE 8653, SAE 8655, SAE 8660, and SAE 9262.

1.02 Mean Carbon Content of SAE Specification—These are straight chromium electric furnace steels used primarily for the races and balls or rollers of antifriction bearings. They are also used for other parts requiring high hardness and wear resistance. The compositions of the three steels are identical, except for a variation in chromium, with a corresponding variation in hardenability.

The low-hardenability steel in the 1.02-mean-carbon-content-classification is SAE 50100.

The medium-hardenability steels in the 1.02-mean-carbon-content classification are SAE 51100 and SAE 52100.

Heat-Treatments—Typical treatments are given in Table 4.

Resulfurized Steel—Some of the alloy steels (SAE 4024, SAE 4028, and SAE 8641) are resulfurized to give better machinability at a relatively high hardness.

Chromium-Nickel Austenitic Steels (Not Capable of Heat-Treatment)

Table 5 gives typical heat-treatments for these chromium-nickel austenitic steels.

SAE 30301	This steel is capable of attaining high tensile strength and ductility by moderate or severe cold working. It is used largely in the cold-rolled or cold-drawn condition in the form of sheet, strip, and wire. Its corrosion resistance is good but not equal to SAE 30302.
30302	This is the most widely used of the general-purpose austenitic chromium-nickel stainless steels. It is used for deep drawing largely in the annealed condition. It can be worked to high tensile strengths but with slightly lower ductility than SAE 30301.
30303F	This is a free-machining type recommended for the manufacture of parts produced on automatic machines. Caution must be used in forging this steel.
30304	This is similar to SAE 30302 but somewhat superior in corrosion resistance and having superior welding properties for certain types of equipment.
30305	This is similar to SAE 30304 but capable of lower hardness. It has greater ductility with slower work-hardening tendency.
30309	This steel has high heat-resisting qualities and is resistant to oxidation at temperatures up to about 1800 F.
30310	This steel has the highest heat-resisting properties of any of the chromium-nickel steels listed herewith and is used to resist oxidation at temperatures up to about 1900 F.
30316	This steel is recommended for use in parts where unusual resistance to chemical or salt-water corrosion is necessary. It has superior creep strength at elevated temperatures.

(*Text continued on next page.*)

TABLE 5—*Typical Heat-Treatments for Heat-Treating Grades of Chromium-Nickel Austenitic Steels*

SAE Steels	AISI NO.	TREATMENT NO.	NORMALIZING TEMPERATURE, F	ANNEALING TEMPERATURE, F	HARDENING TEMPERATURE, F	QUENCHING MEDIUM	TEMPER
30301	301	I	—	1800–2100	—	Water or air	—
30302	302	I	—	1800–2100	—	Water or air	—
30303F[b]	303	I	—	1800–2100	—	Water or air	—
30304	304	I	—	1800–2100	—	Water or air	—
30305	305	I	—	1800–2100	—	Water or air	—
30309	309	I	—	1800–2100	—	Water or air	—
30310	310	I	—	1800–2100	—	Water or air	—
30316	316	I	—	1800–2100	—	Water or air	—
30317	317	I	—	1800–2100	—	Water or air	—
30321	321	I	—	1800–2100	—	Water or air	—
30325	325	I	—	1800–2100	—	Water or air	—
30347	347	I	—	1800–2100	—	Water or air	—

[a] Quench to produce full austenitic structure using water or air in accordance with thickness of section. Annealing temperatures given cover process and full annealing as already established and used by industry, the lower end of the range being used for process annealing.
[b] Suffix F denotes a free-machining steel.

30317 This steel is similar to SAE 30316 but has the highest corrosion resistance of all these alloys in many environments.

30321 This steel is recommended for use in the manufacture of welded structures where heat-treatment after welding is not feasible. It is also recommended for use where temperatures up to 1600 F are encountered in serv

30325 This is used for such parts as heat-control shafts.

30347 This steel is similar to SAE 30321 with the following additional statement: This columbium alloy is sometimes preferred to titanium because less columbium is lost in the welding operation.

Stainless Chromium Irons and Steels

Table 6 gives typical heat-treatments for these stainless chromium irons and steels.

SAE 51410 This is a general-purpose stainless steel capable of heat-treatment to show good physical properties. It is used for general stainless applications, both in the heat-treated and annealed conditions, but it is not as resistant to corrosion as SAE 51430 in either the annealed or heat-treated condition.

51414 This is a corrosion- and heat-resisting nickel-bearing chromium steel with somewhat better corrosion resistance than SAE 51410. It will attain slightly higher mechanical properties when heat-treated than SAE 51410. It is used in the form of tempered strip or wire, and in bars and forgings for heat-treated parts.

51416F This is a free-machining grade for the manufacture of parts produced in automatic screw machines.

51420 This steel is capable of heat-treating to a relatively high hardness. It will harden to a maximum of approximately 500 Brinell. It has its maximum corrosion-resisting qualities only in the fully hardened condition. It is used for cutlery and hardened pump shafts among other applications.

51420F This is similar to SAE 51420 except for its free-machining properties.

51430 This is a steel of a high chromium type not capable of heat-treatment and is recommended for use in parts of moderate draw. Corrosion and heat resistance are superior to SAE 51410.

51430F This is simular to SAE 51430 except for its free-machining properties.

51431 This is a nickel-bearing chromium steel designed for heat-treatment to high mechanical properties. Its corrosion resistance is superior to other hardenable steels.

51440A This is a hardenable chromium steel with greater quenched hardness than SAE 51420 and greater toughness than SAE 51440B and 51440C. Maximum corrosion resistance is obtained in the fully hardened and polished condition.

(*Text continued on next page.*)

TABLE 6—*Typical Heat-Treatments for Heat-Treating Grades of Stainless Chromium Irons and Steels*

SAE Steels	AISI NO.	TREATMENT NO.	NORMALIZING TEMPERATURE, F	SUBCRITICAL ANNEALING TEMPERATURE, F	FULL ANNEALING[a] TEMPERATURE, F	HARDENING TEMPERATURE, F	QUENCHING MEDIUM	TEMPER
51410	410	I	—	1300–1350[b]	1550–1650	—	Oil or air	To desired hardness
		II	—	—	—	1750–1850		
51414	414	I	—	1200–1250[b]	—	—	Oil or air	To desired hardness
		II	—	—	—	1750–1850		
51416	416	I	—	1300–1350[b]	1550–1650	—	Oil or air	To desired hardness
		II	—	—	—	1750–1850		
51420	420	I	—	1350–1450[b]	1550–1650	—	Oil or air	To desired hardness
		II	—	—	—	1800–1850		
51420F[c]	—	I	—	1350–1450[b]	1550–1650	—	Oil or air	To desired hardness
		II	—	—	—	1800–1850		
51430	430	I	—	1400–1500[d]	—	—	—	—
51430F[c]	—	I	—	1250–1500[d]	—	—	—	—
51431	431	I	—	1150–1225[b]	—	1800–1900	Oil or air	To desired hardness
51440A[c]	440A[c]	I	—	1350–1440[b]	1550–1650	1850–1950	Oil or air	To desired hardness
51440B[c]	440B[c]							
51440C[c]	440C[c]							
51440F[c]	—							
51442	442	I	—	1400–1500[d]	—	—	—	—
51446	446	I	—	1500–1650[b]	—	—	—	—
51501	501	I	—	1325–1375[d]	1525–1600	1600–1700	Oil or air	To desired hardness

[a] Cool slowly in furnace.
[b] Usually aircooled but may be furnace cooled.
[c] Suffixes **A, B,** and **C** denote three types of steel differing only in carbon content. Suffix **F** denotes a free-machining steel.
[d] Cool rapidly in air.

51440B	This is a hardenable chromium steel with greater quenched hardness than SAE 51440A. Maximum corrosion resistance is obtained in the fully hardened and polished condition. The steel is capable of hardening to 50–60 Rockwell C depending upon carbon content.
51440C	This steel has the greatest quenched hardness and wear resistance upon heat-treatment of any corrosion- or heat-resistant steel.
51440F	This is the same as SAE 51440C, except for its free-machining characteristics.
51442	This is a corrosion- and heat-resisting chromium steel with corrosion-resisting properties slightly better than SAE 51430 and with good scale resistance up to 1600 F.
51446	This is a corrosion- and heat-resisting steel with maximum amount of chromium consistent with commercial malleability. It is used principally for parts which must resist high temperatures in service without scaling. It resists oxidation up to 2000 F.
51501	This is used for its heat and corrosion resistance and good mechanical properties at temperatures up to approximately 1000 F.

Physical Properties of Steels

SAE General Information

Report of Iron and Steel Division approved January 1932 and last revised January 1942.

The information contained in the conventional physical property charts has been reorganized to present a clearer picture for the engineer as to how hardness is related to tensile strength, yield strength, and ductility.

Charts (Figs. 1–4) were prepared by replotting the information contained in physical property charts as published by steel companies and alloy suppliers and which are similar to those charts formerly appearing in the SAE Handbook, showing the effect of tempering temperature on the physical properties of steel.

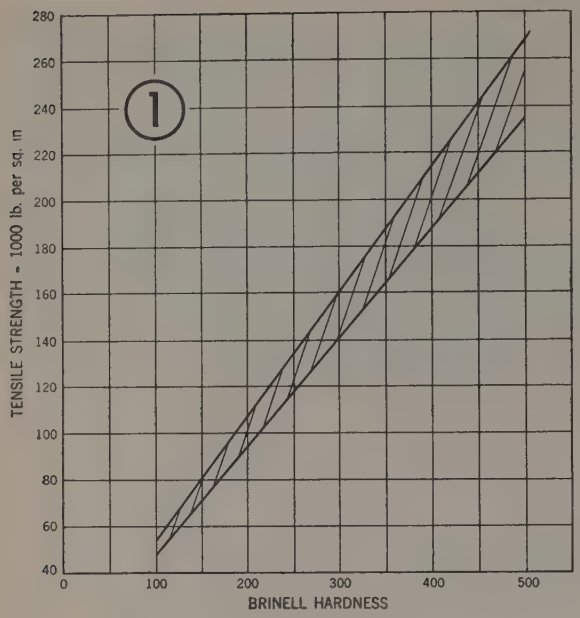
These summary charts illustrate the principle that regardless of composition, steels of the same hardness produced by tempering after hardening, will have the same tensile strength and yield strength. The chart showing the relation between ductility and hardness illustrates the fact that the reduction of area varies directly as the hardness and that for a given hardness the reduction of area is higher for alloy steels than for plain carbon steels.

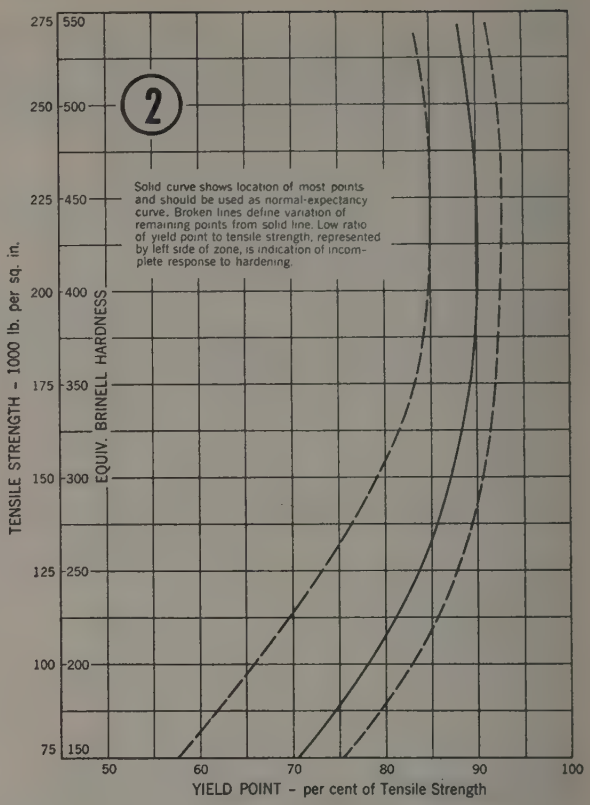
It is evident from these curves that steels of the same hardness have about the same physical properties, so that any one of several different compositions would yield the same results. For some specific application then, the first thing to be determined is what composition is required to obtain proper hardening in the size section involved. This information is not contained in physical property charts but must be determined by means of a hardenability test. Methods for making this hardenability test and interpretation of the test results are provided in the SAE Recommended Practice for the Method of Determining Hardenability. Having selected a steel that will harden in the size section under consideration, the engineer must decide from the service stresses imposed on the machine part what tensile properties are required in the part. These tensile properties may then be converted to hardness values from the charts given here; and from the chart showing the effect of tempering temperature on hardness, the proper tempering temperature to obtain this hardness can be selected.

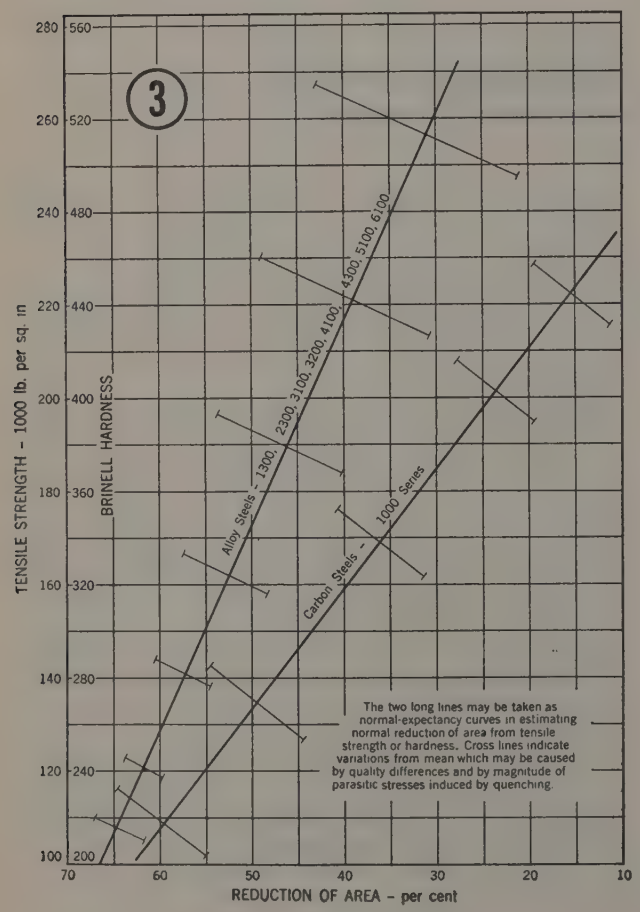
The chart showing the effect of tempering temperature on hardness is also a summary of information contained in a large number of physical property charts published by steel companies and alloy suppliers and represents, as do the charts on tensile strength, yield strength, and reduction of area, data on the following alloy and carbon types with carbon contents from 0.30 to 0.50%: SAE 1000, 1100, 1300, 2300, 3100, 3200, 4100, 4300, 4600, 5100, and 6100. The charts showing the relation between hardness and yield strength, and hardness and reduction of area, represent steel in the quenched and tempered condition. The chart showing the relation between hardness and tensile strength represents these steels in the hardened and tempered, as-rolled, annealed, and normalized conditions.

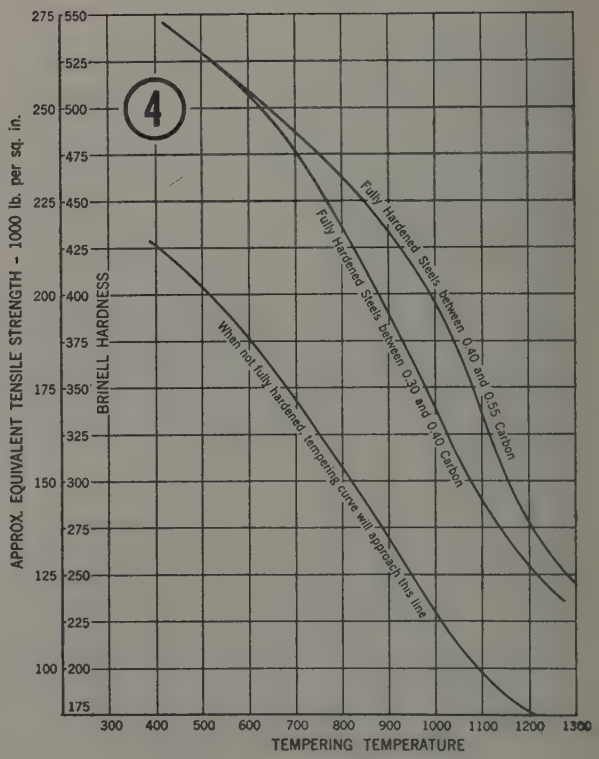
Physical-property values obtained from these few summary charts will be as accurate as the information formerly available in a large number of charts, each representing an individual type of steel. For more exact information it would be necessary to make tests on samples from individual heats of steel.

(*Charts follow on next page.*)


1
TENSILE STRENGTH - 1000 lb. per sq. in
BRINELL HARDNESS
280
260
240
220
200
180
160
140
120
100
80
60
40
0
100
200
300
400
500


2
TENSILE STRENGTH - 1000 lb. per sq. in.
EQUIV. BRINELL HARDNESS
Solid curve shows location of most points and should be used as normal-expectancy curve. Broken lines define variation of remaining points from solid line. Low ratio of yield point to tensile strength, represented by left side of zone, is indication of incomplete response to hardening.
YIELD POINT - per cent of Tensile Strength
275
250
225
200
175
150
125
100
75
550
500
450
400
350
300
250
200
150
50
60
70
80
90
100


3
TENSILE STRENGTH - 1000 lb. per sq. in
BRINELL HARDNESS
Alloy Steels - 1300, 2300, 3100, 3200, 4100, 4300, 5100, 6100
Carbon Steels - 1000 Series
The two long lines may be taken as normal-expectancy curves in estimating normal reduction of area from tensile strength or hardness. Cross lines indicate variations from mean which may be caused by quality differences and by magnitude of parasitic stresses induced by quenching.
REDUCTION OF AREA - per cent
280
260
240
220
200
180
160
140
120
100
560
520
480
440
400
360
320
280
240
200
70
60
50
40
30
20
10


4
APPROX. EQUIVALENT TENSILE STRENGTH - 1000 lb. per sq. in.
BRINELL HARDNESS
Fully Hardened Steels between 0.40 and 0.55 Carbon
Fully Hardened Steels between 0.30 and 0.40 Carbon
When not fully hardened, tempering curve will approach this line.
TEMPERING TEMPERATURE
275
250
225
200
175
150
125
100
550
525
500
475
450
425
400
375
350
325
300
275
250
225
200
175
300
400
500
600
700
800
900
1000
1100
1200
1300

Estimated Mechanical Properties of Hot-Rolled and Cold-Finished Carbon Steel Bars

SAE General Information

Report of Iron and Steel Technical Committee approved January 1950.

The mechanical properties listed below are given only as a matter of general information. They do not form a part or requirement of any specification unless each instance is approved by the source of supply. The properties in Table 1 can generally be expected from bars in sizes ranging from ¾ to 1¼ in. based on the standard round tension test specimen with 2-in. gage length.

Sizes under ¾ in. will show slightly higher strength than those shown in Table 1. The mass effect of larger sections has a direct influence on mechanical properties and results in slightly lower values as the section increases.

Mechanical values for turned and polished or turned and ground types of cold-finished material will correspond to the hot-rolled values.

The cold-drawn values are based on conventional production from hot-rolled bars. When required, these properties may be varied by modified cold-drawing practices. Grades over SAE 1050 are commonly produced in conjunction with thermal treatment.

The machinability ratings listed for cold-drawn material are based on a value of 100 for Grade 1112.

TABLE 1—*Mechanical Properties of SAE Carbon Steel Bars*

SAE and AISI No.	Estimated minimum values						Average machinability rating (cold-drawn 1112 = 100)	SAE and AISI No.	Estimated minimum values						Average machinability rating (cold-drawn 1112 = 100)
	Type of processing	Tensile strength, psi	Yield strength, psi	Elongation in 2 in., %	Reduction in area, %	Brinell hardness			Type of processing	Tensile strength, psi	Yield strength, psi	Elongation in 2 in., %	Reduction in area, %	Brinell hardness	
1006	Hot-rolled	43,000	24,000	30	55	86		1030	Hot-rolled	68,000	37,500	20	42	137	
	Cold-drawn	48,000	41,000	20	45	95	48		Cold-drawn	76,000	64,000	12	35	149	68
1008	Hot-rolled	44,000	24,500	30	55	86		1033	Hot-rolled	72,000	39,500	18	40	143	
	Cold-drawn	49,000	41,500	20	45	95	50		Cold-drawn	80,000	67,000	12	35	163	68
1010	Hot-rolled	47,000	26,000	28	50	95		1034	Hot-rolled	70,000	38,500	18	40	143	
	Cold-drawn	53,000	44,000	20	40	105	52		Cold-drawn	78,000	65,500	12	35	156	64
1015	Hot-rolled	50,000	27,500	28	50	101		1035	Hot-rolled	72,000	39,500	18	40	143	
	Cold-drawn	56,000	47,000	18	40	111	53		Cold-drawn	80,000	67,000	12	35	163	65
1016	Hot-rolled	55,000	30,000	25	50	111		1036	Hot-rolled	83,000	45,500	16	40	163	
	Cold-drawn	61,000	51,000	18	40	121	64		Cold-drawn	92,000	77,500	12	35	187	54
1017	Hot-rolled	53,000	29,000	26	50	105		1038	Hot-rolled	75,000	41,000	18	40	149	
	Cold-drawn	59,000	49,000	18	40	116	56		Cold-drawn	83,000	70,000	12	35	163	62
1018	Hot-rolled	58,000	32,000	25	50	116		1039	Hot-rolled	79,000	43,500	16	40	156	
	Cold-drawn	64,000	54,000	15	40	126	66		Cold-drawn	88,000	74,000	12	35	179	61
1019	Hot-rolled	59,000	32,500	25	50	116		1040	Hot-rolled	76,000	42,000	18	40	149	
	Cold-drawn	66,000	55,000	15	40	131	70		Cold-drawn	85,000	71,000	12	35	170	62
1020	Hot-rolled	55,000	30,000	25	50	111		1041	Hot-rolled	92,000	51,000	15	40	187	
	Cold-drawn	61,000	51,000	15	40	121	58		Cold-drawn	102,500	87,000	10	30	207	50
1022	Hot-rolled	62,000	34,000	23	47	121		1042	Hot-rolled	80,000	44,000	16	40	163	
	Cold-drawn	69,000	58,000	15	40	137	69		Cold-drawn	89,000	75,000	12	35	179	60
1024	Hot-rolled	74,000	41,000	20	42	149		1043	Hot-rolled	82,000	45,000	16	40	163	
	Cold-drawn	82,000	69,000	12	35	163	64		Cold-drawn	91,000	77,000	12	35	179	58
1025	Hot-rolled	58,000	32,000	25	50	116		1045	Hot-rolled	82,000	45,000	16	40	163	
	Cold-drawn	64,000	54,000	15	40	126	58		Cold-drawn	91,000	77,000	12	35	179	55
1027	Hot-rolled	75,000	41,000	18	40	149		1046	Hot-rolled	85,000	47,000	15	40	170	
	Cold-drawn	83,000	70,000	12	35	163	64		Cold-drawn	94,000	79,000	12	35	187	54

(*Continued on next page.*)

TABLE 1—(*Concluded*)

SAE AND AISI No.	Type of processing	Tensile strength, psi	Yield strength, psi	Elongation in 2 in., %	Reduction in area, %	Brinell hardness	Average machinability rating (cold-drawn 1112 = 100)
1049	Hot-rolled	87,000	48,000	15	35	179	
	Cold-drawn	97,000	81,500	10	30	197	53
1050	Hot-rolled	90,000	49,500	15	35	179	
	Cold-drawn	100,000	84,000	10	30	197	51
1052	Hot-rolled	108,000	59,500	12	30	217	—
1055	Hot-rolled	94,000	51,500	12	30	192	—
1060	Hot-rolled	98,000	54,000	12	30	201	—
1062	Hot-rolled	103,000	56,500	12	30	212	—
1064	Hot-rolled	97,000	53,500	12	30	201	—
1065	Hot-rolled	100,000	55,000	12	30	207	—
1066	Hot-rolled	106,000	58,000	12	30	217	—
1070	Hot-rolled	102,000	56,000	12	30	212	—
1074	Hot-rolled	105,000	58,000	12	30	217	—
1078	Hot-rolled	100,000	55,000	12	30	207	—
1080	Hot-rolled	112,000	61,500	10	25	229	—
1085	Hot-rolled	121,000	66,500	10	25	248	—
1086	Hot-rolled	112,000	61,500	10	25	229	—
1090	Hot-rolled	122,000	67,000	10	25	248	—
1095	Hot-rolled	120,000	66,000	10	25	248	—
(*Bessemer*)							
1111	Hot-rolled	60,000	33,000	25	45	121	
	Cold-drawn	67,000	56,000	10	35	131	92
1112	Hot-rolled	61,000	33,500	25	45	121	
	Cold-drawn	68,000	57,000	10	35	137	100
1113	Hot-rolled	61,000	33,500	25	45	121	
	Cold-drawn	68,000	57,000	10	35	137	137
1109	Hot-rolled	50,000	27,500	30	50	101	
	Cold-drawn	56,000	47,000	20	40	121	75
1114	Hot-rolled	57,000	31,500	28	50	111	
	Cold-drawn	63,500	53,000	20	40	126	81
1115	Hot-rolled	55,000	30,000	25	50	111	
	Cold-drawn	61,000	51,000	20	40	121	80
1116	Hot-rolled	63,000	35,000	23	47	126	
	Cold-drawn	70,000	60,000	15	40	143	91
1117	Hot-rolled	62,000	34,000	23	47	121	
	Cold-drawn	69,000	58,000	15	40	137	87
1118	Hot-rolled	65,000	36,000	23	47	131	
	Cold-drawn	72,000	61,000	15	40	143	84
1119	Hot-rolled	62,000	34,000	23	47	121	
	Cold-drawn	69,000	58,000	15	40	137	100
1120	Hot-rolled	62,000	34,000	23	47	121	
	Cold-drawn	69,000	58,000	15	40	137	80
1126	Hot-rolled	64,000	35,000	23	47	126	
	Cold-drawn	71,000	59,500	15	40	143	78
1132	Hot-rolled	83,000	45,500	16	40	167	
	Cold-drawn	92,000	77,000	12	35	183	75
1137	Hot-rolled	88,000	48,000	15	35	179	
	Cold-drawn	98,000	82,000	10	30	197	71
1138	Hot-rolled	73,000	40,000	18	40	149	
	Cold-drawn	81,000	68,000	12	35	156	74
1140	Hot-rolled	79,000	43,500	16	40	156	
	Cold-drawn	88,000	74,000	12	35	170	71
1141	Hot-rolled	94,000	51,500	15	35	187	
	Cold-drawn	105,000	88,000	10	30	212	69
1144	Hot-rolled	97,000	53,000	15	35	197	
	Cold-drawn	108,000	90,000	10	30	217	83
1145	Hot-rolled	85,000	47,000	15	40	170	
	Cold-drawn	94,000	80,000	12	35	187	63
1146	Hot-rolled	85,000	47,000	15	40	170	
	Cold-drawn	94,000	80,000	12	35	187	69
1151	Hot-rolled	92,000	50,500	15	35	187	
	Cold-drawn	102,000	86,000	10	30	207	66

Definitions of Heat-Treating Terms

SAE General Information

Report of Iron and Steel Division approved June 1911 and last revised November 1950.

[*These definitions were prepared by the Joint Committee on Definitions of Terms Relating to Heat-Treatment appointed by the American Society for Testing Materials, the American Society for Metals, the American Foundrymen's Association, and the SAE.*]

This glossary is not intended to be a specification, and it should not be interpreted as such. Since this is intended to be strictly a set of definitions, temperatures have been omitted purposely.

Ac_{cm}, Ac_1, Ac_3, Ac_4—Defined under *transformation temperature.*

Ae_{cm}, Ae_1, Ae_3, Ae_4—Defined under *transformation temperature.*

age hardening—Hardening by aging, usually after rapid cooling or cold working. See *aging.*

aging—In a metal or alloy, a change in properties that generally occurs slowly at room temperature and more rapidly at higher temperatures. See also *age hardening, artificial aging, interrupted aging, natural aging, overaging, precipitation hardening, precipitation heat-treatment, progressive aging, quench aging,* and *strain aging.*

annealing—Heating to and holding at a suitable temperature and then cooling at a suitable rate, for such purposes as reducing hardness, improving machinability, facilitating cold working, producing a desired microstructure, or obtaining desired mechanical, physical, or other properties. When applicable, the following more specific terms should be used: black annealing, blue annealing, box annealing, bright annealing, flame annealing, full annealing, graphitizing, intermediate annealing, isothermal annealing, malleablizing, process annealing, quench annealing, recrystallization annealing, and spheroidizing.

Definitions of the above terms are given in their alphabetic positions in this glossary.

When applied to ferrous alloys, the term "annealing," without qualification, implies full annealing.

When applied to nonferrous alloys, the term "annealing" implies a heat-treatment designed to soften a cold-worked structure by recrystallization or subsequent grain growth or to soften an age-hardened alloy by causing a nearly complete precipitation of the second phase in relatively coarse form.

Any process of annealing will usually reduce stresses, but if the treatment is applied for the sole purpose of such relief it should be designated *stress relieving.*

Ar_{cm}, Ar_1, Ar_3, Ar_4, Ar''—Defined under *transformation temperature.*

artificial aging—Aging above room temperature. See *aging* and *precipitation heat-treatment.* Compare with *natural aging.*

austempering—Quenching a ferrous alloy from a temperature above the transformation range, in a medium having a rate of heat abstraction high enough to prevent the formation of high-temperature transformation products, and then holding the alloy, until transformation is complete, at a temperature below that of pearlite formation and above that of martensite formation.

austenitizing—Forming austenite by heating a ferrous alloy into the transformation range (partial austenitizing) or above the transformation range (complete austenitizing).

baking—Heating to a low temperature in order to remove gases.

black annealing—Box annealing or pot annealing ferrous alloy sheet, strip, or wire. See *box annealing.*

blank carburizing—Simulating the carburizing operation without introducing carbon. This is usually accomplished by using an inert material in place of the carburizing agent, or by applying a suitable protective coating to the ferrous alloy.

blank nitriding—Simulating the nitriding operation without introducing nitrogen. This is usually accomplished by using an inert material in place of the nitriding agent, or by applying a suitable protective coating to the ferrous alloy.

blue annealing—Heating hot-rolled ferrous sheet in an open furnace to a temperature within the transformation range and then cooling in air, in order to soften the metal. The formation of a bluish oxide on the surface is incidental.

bluing—Subjecting the scale-free surface of a ferrous alloy to the action of air, steam, or other agents at a suitable temperature, thus forming a thin blue film of oxide and improving the appearance and resistance to corrosion.

Note: This term is ordinarily applied to sheet, strip, or finished parts. It is used also to denote the heating of springs after fabrication, in order to improve their properties.

box annealing—Annealing a metal or alloy in a sealed container under conditions that minimize oxidation. In box annealing a ferrous alloy, the charge is usually heated slowly to a temperature below the transformation range, but sometimes above or within it, and is then cooled slowly; this process is also called "close annealing" or "pot annealing". See *black annealing.*

bright annealing—Annealing in a protective medium to prevent discoloration of the bright surface.

burning—Permanently damaging a metal or alloy by heating to cause either incipient melting or intergranular oxidation. See *overheating.*

carbonitriding—Introducing carbon and nitrogen into a solid ferrous alloy by holding above Ac_1 in an atmosphere that contains suitable gases such as hydrocarbons, carbon monoxide, and ammonia. The carbonitrided alloy is usually quench hardened.

carburizing—Introducing carbon into a solid ferrous alloy by holding above Ac_1 in contact with a suitable carbonaceous material. The carburized alloy is usually quench hardened.

case—In a ferrous alloy, the outer portion that has been made harder than the inner portion or *core* by *case hardening.*

case hardening—Hardening a ferrous alloy so that the outer portion or case is made substantially harder than the inner portion or core. Typical processes used for case hardening are *carburizing, cyaniding, carbonitriding, nitriding, induction hardening,* and *flame hardening.*

cementation—The introduction of one or more elements into the outer portion of a metal object by means of diffusion at high temperature.

cold-treatment—Cooling to a low temperature for the purpose of obtaining desired conditions or properties, such as dimensional or structural stability.

controlled cooling—Cooling from an elevated temperature in a

predetermined manner, to avoid hardening, cracking, or internal damage, or to produce a desired microstructure. This cooling usually follows a hot-forming operation.

core—In a ferrous alloy, the inner portion that is softer than the outer portion or *case*.

critical range or **critical temperature range**—Synonymous with *transformation range*, which is preferred.

cyaniding—Introducing carbon and nitrogen into a solid ferrous alloy by holding above Ac_1 in contact with molten cyanide of suitable composition. The cyanided alloy is usually quench hardened.

decarburization—The loss of carbon from the surface of a ferrous alloy as a result of heating in a medium that reacts with the carbon.

differential heating—Heating that produces a temperature distribution within an object in such a way that, after cooling, various parts have different properties as desired.

direct quenching—Quenching carburized parts directly from the carburizing operation.

drawing—A misnomer for *tempering*.

flame annealing—Annealing in which the heat is applied directly by a flame.

flame hardening—Quench hardening in which the heat is applied directly by a flame.

fog quenching—Quenching in a fine vapor or mist.

full annealing—Annealing a ferrous alloy by austenitizing and then cooling slowly through the transformation range. The austenitizing temperature for hypoeutectoid steel is usually above Ac_3 and for hypereutectoid steel usually between Ac_1 and Ac_{cm}.

gas cyaniding—A misnomer for *carbonitriding*.

graphitizing—Annealing a ferrous alloy in such a way that some or all of the carbon is precipitated as graphite.

hardenability—In a ferrous alloy, the property that determines the depth and distribution of hardness induced by quenching.

hardening—Increasing the hardness by suitable treatment, usually involving heating and cooling. When applicable, the following more specific terms should be used: *age hardening*, *case hardening*, *flame hardening*, *induction hardening*, *precipitation hardening*, and *quench hardening*.

heat-treatment—Heating and cooling a solid metal or alloy in such a way as to obtain desired conditions or properties. Heating for the sole purpose of hot working is excluded from the meaning of this definition.

homogenizing—Holding at high temperature to eliminate or decrease chemical segregation by diffusion.

hot quenching—Quenching in a medium at an elevated temperature.

induction hardening—Quench hardening in which the heat is generated by electrical induction.

induction heating—Heating by electrical induction.

intermediate annealing—Annealing wrought metals at one or more stages during manufacture and before final thermal treatment.

interrupted aging—Aging at two or more temperatures, by steps, and cooling to room temperature after each step. See *aging* and compare with *progressive aging*.

interrupted quenching—Quenching in which the metal object being quenched is removed from the quenching medium while the object is at a temperature substantially higher than that of the quenching medium. See also *time quenching*.

isothermal annealing—Austenitizing a ferrous alloy and then cooling to and holding at a temperature at which austenite transforms to a relatively soft ferrite-carbide aggregate.

isothermal transformation—A change in phase at any constant temperature.

malleablizing—Annealing white cast iron in such a way that some or all of the combined carbon is transformed to graphite or, in some instances, part of the carbon is removed completely.

martempering—Quenching an austenitized ferrous alloy in a medium at a temperature in the upper part of the martensite range, or slightly above that range, and holding in the medium until the temperature throughout the alloy is substantially uniform. The alloy is then allowed to cool in air through the martensite range.

martensite range—The temperature interval between M_s and M_f.

M_f—Defined under *transformation temperature*.

M_s (or **Ar″**)—Defined under *transformation temperature*.

natural aging—Spontaneous aging of a supersaturated solid solution at room temperature. See *aging* and compare with *artificial aging*.

nitriding—Introducing nitrogen into a solid ferrous alloy by holding at a suitable temperature (below Ac_1 for ferritic steels) in contact with a nitrogenous material, usually ammonia or molten cyanide of appropriate composition. Quenching is not required to produce a hard case.

normalizing—Heating a ferrous alloy to a suitable temperature above the transformation range and then cooling in still air to room temperature.

overaging—Aging under conditions of time and temperature greater than those required to obtain maximum change in a certain property, so that the property is altered in the direction of the initial value. See *aging*.

overheating—Heating a metal or alloy to such a high temperature that its properties are impaired. When the original properties cannot be restored by further heat-treating, by mechanical working, or by a combination of working and heat-treating, the overheating is known as *burning*.

patenting—In wire making, a heat-treatment applied to medium-carbon or high-carbon steel before the drawing of wire or between drafts. This process consists in heating to a temperature above the transformation range and then cooling to a temperature below Ae_1 in air or in a bath of molten lead or salt.

postheating—Heating weldments immediately after welding, for tempering, for stress relieving, or for providing a controlled rate of cooling to prevent formation of a hard or brittle structure.

precipitation hardening—Hardening caused by the precipitation of a constituent from a supersaturated solid solution. See also *age hardening* and *aging*.

precipitation heat-treatment—Artificial aging in which a constituent precipitates from a supersaturated solid solution. See *artificial aging*, *interrupted aging*, and *progressive aging*.

preheating—Heating before some further thermal or mechanical treatment. For tool steel, heating to an intermediate temperature immediately before final austenitizing. For some nonferrous alloys, heating to a high temperature for a long time in order to homogenize the structure before working.

process annealing—In the sheet and wire industries, heating a ferrous alloy to a temperature close to, but below, the lower limit of the transformation range and then cooling, in order to soften

ıe alloy for further cold working.

progressive aging—Aging by increasing the temperature in eps or continuously during the aging cycle. See *aging* and ɔmpare with *interrupted aging*.

pseudocarburizing—See *blank carburizing*.

pseudonitriding—See *blank nitriding*.

quench aging—Aging induced by rapid cooling after *solution eat-treatment*.

quench annealing—Annealing an austenitic ferrous alloy by *ɔlution heat-treatment*.

quench hardening—Hardening a ferrous alloy by austenitizing nd then cooling rapidly enough so that some or all of the ıstenite transforms to martensite. The austenitizing tempera-ıre for hypoeutectoid steels is usually above Ac_3 and for hyper-ıtectoid steels usually between Ac_1 and Ac_{cm}.

quenching—Rapid cooling. When applicable, the following ıore specific terms should be used: *direct quenching*, *fog quench-ıg*, *hot quenching*, *interrupted quenching*, *selective quenching*, *ɔray quenching*, and *time quenching*.

recrystallization annealing—Annealing cold-worked metal to roduce a new grain structure without phase change.

secondary hardening—Tempering certain alloy steels at cer-ain temperatures so that the resulting hardness is greater than ıat obtained by tempering the same steel at some lower tem-erature for the same time.

selective heating—Heating only certain portions of an object ɔ that they have the desired properties after cooling.

selective quenching—Quenching only certain portions of an bject.

soaking—Prolonged holding at a selected temperature.

solution heat-treatment—Heating an alloy to a suitable tem-erature, holding at that temperature long enough to allow one r more constituents to enter into solid solution, and then cooling apidly enough to hold the constituents in solution. The alloy left in a supersaturated, unstable state and may subsequently xhibit *quench aging*.

spheroidizing—Heating and cooling to produce a spheroidal r globular form of carbide in steel. Spheroidizing methods requently used are:

1. Prolonged holding at a temperature just below Ae_1.
2. Heating and cooling alternately between temperatures ıat are just above and just below Ae_1.
3. Heating to a temperature above Ae_1 or Ae_3 and then cooling ery slowly in the furnace or holding at a temperature just elow Ae_1.
4. Cooling at a suitable rate from the minimum temperature t which all carbide is dissolved, to prevent the re-formation of a arbide network, and then reheating in accordance with Method or 2 above. (Applicable to hypereutectoid steel containing a arbide network.)

spray quenching—Quenching in a spray of liquid.

stabilizing treatment—Any treatment intended to stabilize ıe structure of an alloy or the dimensions of a part. (1) Heating ustenitic stainless steels that contain titanium, columbium, or antalum to a suitable temperature below that of a full anneal ı order to inactivate the maximum amount of carbon by pre-ipitation as a carbide of titanium, columbium, or tantalum. (2) Transforming retained austenite in parts made from tool steel. (3) Precipitating a constituent from a nonferrous solid solution to improve the workability, to decrease the tendency of certain alloys to age harden at room temperature, or to obtain dimensional stability.

strain aging—Aging induced by cold working. See *aging*.

stress relieving—Heating to a suitable temperature, holding long enough to reduce residual stresses and then cooling slowly enough to minimize the development of new residual stresses.

temper brittleness—Brittleness that results when certain steels are held within, or are cooled slowly through, a certain range of temperature below the transformation range. The brittleness is revealed by notched-bar impact tests at or below room temperature.

tempering—Reheating a quench-hardened or normalized ferrous alloy to a temperature below the transformation range and then cooling at any rate desired.

time quenching—Interrupted quenching in which the duration of holding in the quenching medium is controlled.

transformation ranges or **transformation temperature ranges**—Those ranges of temperature within which austenite forms during heating and transforms during cooling. The two ranges are distinct, sometimes overlapping but never coinciding. The limiting temperatures of the ranges depend on the composition of the alloy and on the rate of change of temperature, particularly during cooling. See *transformation temperature*.

transformation temperature—The temperature at which a change in phase occurs. The term is sometimes used to denote the limiting temperature of a transformation range. The following symbols are used for iron and steels:

Ac_{cm}—In hypereutectoid steel, the temperature at which the solution of cementite in austenite is completed during heating.

Ac_1—The temperature at which austenite begins to form during heating.

Ac_3—The temperature at which transformation of ferrite to austenite is completed during heating.

Ac_4—The temperature at which austenite transforms to delta ferrite during heating.

Ae_1, Ae_3, Ae_{cm}, Ae_4—The temperatures of phase changes at equilibrium.

Ar_{cm}—In hypereutectoid steel, the temperature at which precipitation of cementite starts during cooling.

Ar_1—The temperature at which transformation of austenite to ferrite or to ferrite plus cementite is completed during cooling.

Ar_3—The temperature at which austenite begins to transform to ferrite during cooling.

Ar_4—The temperature at which delta ferrite transforms to austenite during cooling.

M_s (or **Ar″**)—The temperature at which transformation of austenite to martensite starts during cooling.

M_f—The temperature at which martensite formation finishes during cooling.

Note: All these changes except the formation of martensite occur at lower temperatures during cooling than during heating, and depend on the rate of change of temperature.

Low-Temperature Properties of Ferrous Materials

SAE General Information

Report of Iron and Steel Technical Committee approved January 1951.

[*This is a condensation of SAE Special Publication SP-65, "Low-Temperature Properties of Ferrous Materials."*

Civilian and military requirements for ferrous materials in aircraft, marine, and ground vehicles and railroad equipment are most often concerned with temperatures down to about −75 F, while in the chemical industries temperatures may range down to −320 F or lower. In an effort to cover all users' problems, available data were reviewed for conditions below room temperature. The following paragraphs are an attempt to summarize these data.]

General Effect of Low Temperature on Mechanical Properties of Ferrous Materials

Conventional engineering tests of ferrous materials have provided information to show that, as the temperature of testing is decreased below room temperature, hardness, yield strength, fatigue strength, and, except for highly embrittled materials, tensile strength increase. This is not so, however, for ductility, manifested by the degree of permanent deformation before fracture by stress in tension, and for toughness, manifested by the amount of energy absorbed before fracture. With respect to these two properties, ferrous materials fall into one of two groups, namely, those which remain ductile at low temperatures and those which become embrittled.

It is a characteristic of the body-centered-cubic ferritic materials to show brittle behavior at some low temperature, the materials differing among themselves only in the temperature at which ductility in a specific test vanishes. Austenitic-type materials, of face-centered-cubic structure, on the other hand, tend to remain ductile over most ranges of low temperatures that have been investigated. The fracture behavior of ferritic materials is known to change profoundly with lowering temperature, the change often being characterized by a sudden loss in toughness or ductility. The temperature of change from ductile to brittle behavior is frequently referred to as the transition temperature, though this temperature need not be and usually is not the same when determined by different test procedures.

Progress has been made in correlating results of conventional tests with service performance of materials at low temperatures, but designers are cautioned to use extreme care in interpreting such results in terms of material performance. All conventional tests for embrittlement provide arbitrary measures of the ability of material to resist fracture under conditions of restriction on deformation. These tests are incapable of integrating all the variables significant to the problem of embrittlement. For that reason, it seems necessary to place reliance on only those tests which most nearly simulate conditions in service or at least which have been shown by experience to give satisfactory indications of the behavior of material in its particular environment.

[1] See A. S. T. M. Proceedings, Vol. 38, 1938, Part 2, pp. 112–132: "Theory of Impact Testing: Influence of Temperature, Velocity of Deformation, and Form and Size of Specimen on Work of Deformation" by D. J. McAdam, Jr. and R. W. Clyne.

[2] See Transactions of the ASM, Vol. 28, 1940, pp. 1–19: "Impact Properties of Some Low Alloy Nickel Steels at Temperatures Down to −200 Fahr." by T. N. Armstrong and A. P. Gagnebin.

Notched-Bar Impact Test Procedures for Measuring Low-Temperature Embrittlement in Ferrous Materials

Embrittlement of ferrous metals most markedly manifests itself by its effect upon the notched-bar impact resistance of materials. Notched-bar impact tests provide the two features necessary to evaluate the ability of metals to resist brittle fracture: an initially high rate of strain induced by an impact blow, and the confining of the strain to a restricted volume of metal in the vicinity of the notch. Also, notched-bar impact tests can be conducted over a wide temperature range so that the influence of temperature upon the ability of metals to resist shock loading can be readily determined.

Influence of Geometry of Specimen—The influence of the geometry of notched-bar impact test specimens upon the impact resistance characteristics of ferrous alloys is explicable on the basis of the degree of constraint which is imposed by the geometry of the test specimen upon the volume of metal immediately adjacent to the fracture. A geometrical shape which restricts the deformation of the specimen during loading will result in greater tendency towards brittle behavior than a geometrical shape which does not inhibit the specimen from bending and otherwise deforming.[1]

Since the dimensions of any standard or nonstandard type of impact test specimen are of necessity equally arbitrary, the real value of impact test data lies in the accumulation of correlated data on the impact resistance characteristics of steels and their performance in service in actual structures.

Influence of Sharpness of Notch—Increasing the sharpness of the notch increases the severity of the test and accentuates the tendency towards brittle behavior, thus raising the temperature of transition from ductile to brittle fracture.[2] See Fig. 1.

Types of Specimens—Fig. 2 illustrates the types of notched

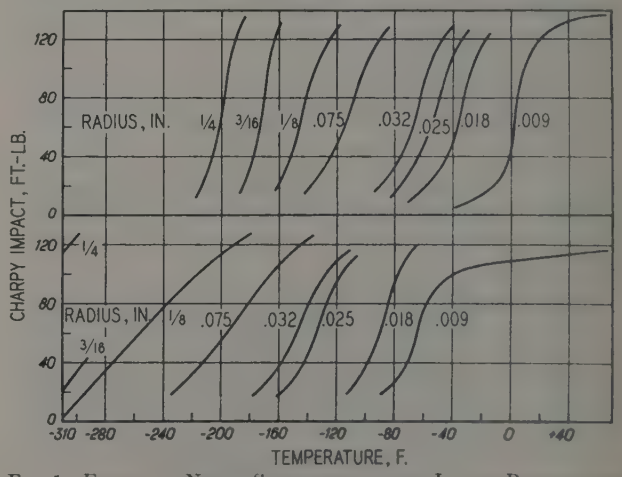
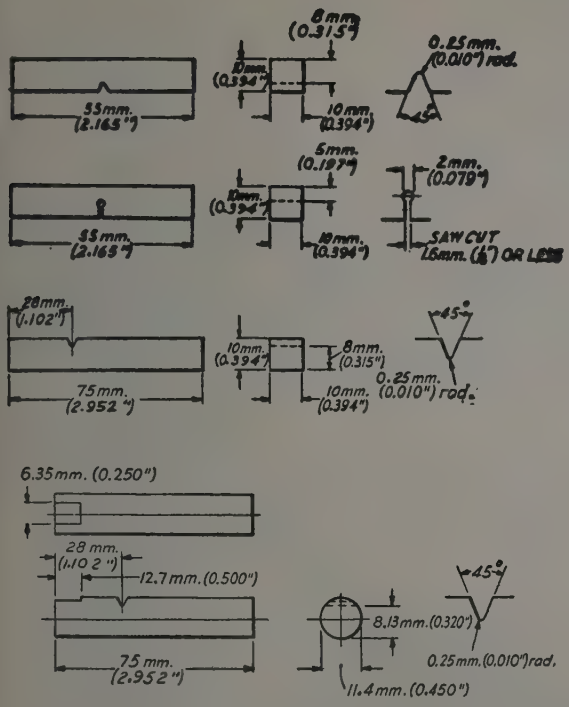


FIG. 1—EFFECT OF NOTCH SHARPNESS ON THE IMPACT PROPERTIES OF A CARBON AND A NICKEL STEEL

Upper curves represent normalized 0.15C steel; lower curves represent normalized 0.15C-2.00Ni steel.

From Transactions of the ASM, Vol. 28, 1940, pp. 1–19: "Impact Properties of Some Low Alloy Nickel Steels at Temperatures Down to −200 Fahr." by R. N. Armstrong and A. P. Gagnebin.



A—Charpy V-notch

B—Charpy keyhole-notch

C—Izod square

Permissible Variations:

Cross-Section Dimensions	±0.025 mm (0.001 in.)
Length of Specimen	±0.25 mm (0.010 in.)
Angle of Notch	±1°

D—Izod round

FIG. 2—IMPACT-TEST SPECIMENS
From ASTM E 23 - 47 T.

bar impact test specimens for measuring the impact resistance of steel at various temperatures. The Charpy V- and keyhole-notch specimens are broken as a simple beam. The square and round Izod impact specimens are broken as a cantilever beam. The Charpy-type specimen is desired because of ease of testing at low temperatures. A variety of notched-tensile, notched-bend, and tear test specimens are also being used.

The type of test specimen chosen for determining the tendency of metal to behave either in a tough or brittle manner at room or reduced temperatures depends upon the relative toughness of the material. For very tough materials, it is necessary to choose specimens providing severe constraint and high strain rates—that is, notched-bar specimens broken by an impact blow. For more brittle materials such as cast iron or very hard steel, unnotched simple-beam type specimens broken either by impact or, in extreme cases, by static loading will suffice for discriminating between more or less brittle materials.

Metallurgical Factors Affecting Low-Temperature Behavior of Ferrous Materials

Metallurgical factors affecting the transition or embrittlement temperature determined by various recognized tests are so manifold and of such different origin that a careful review of the factors is desirable in order to establish their relative importance and relationship.

Influence of Steel Making—Silicon-killed, semikilled, and rimmed steels will, in general, show less favorable impact properties. The transition temperature will be progressively higher for these steels in the order in which they are named, and the absorbed energy at normal temperature will tend to decrease in the same order.

Melting practice has been found to have a definite effect on low-temperature impact values. Carbon steels (0.15 to 0.25% carbon) were found to have improved properties when fully killed with aluminum. This treatment lowers the oxygen content of the steels and produces a fine-grained material.[3] Optimum properties for a given composition and structure are obtained when the steel is fully killed with aluminum.

Influence of Hardenability—The ideal structure to obtain the lowest transition temperature at a given hardness in ferritic steels is tempered martensite, and any deviation from this ideal structure will result in increasing that temperature. Hardenability of steel, which determines the ease with which martensite may be formed is therefore an important factor.

Influence of Structural Components—When stable austenite is the principal component, as in high chromium-nickel stainless steels, impact resistance is high at room temperature and continues to be high at low temperatures though there may be a very gradual decrease at extremely low temperatures.

Martensite tempered to relieve stresses only has low room-temperature impact values, which decrease with lowering tem-

[3] See "Effect of Deoxidation on the Impact Strength of Carbon Steels at Low Temperatures" by C. H. Herty, Jr. and D. L. McBride. Cooperative Bulletin 67 published by the Mining and Metallurgical Advisory Boards to Carnegie Institute of Technology and Bureau of Mines, Pittsburgh, 1934, 43 pp.

peratures and pass from ductile to brittle condition. When tempering temperatures are such that the hardness is decreased, impact values are raised.

A pearlitic-ferritic structure produced by normalizing has a lower room temperature impact resistance and a higher transition temperature than the quenched-and-tempered structure of the same hardness. Bainitic steels fall between the two classes mentioned above.[4] See Fig. 3.

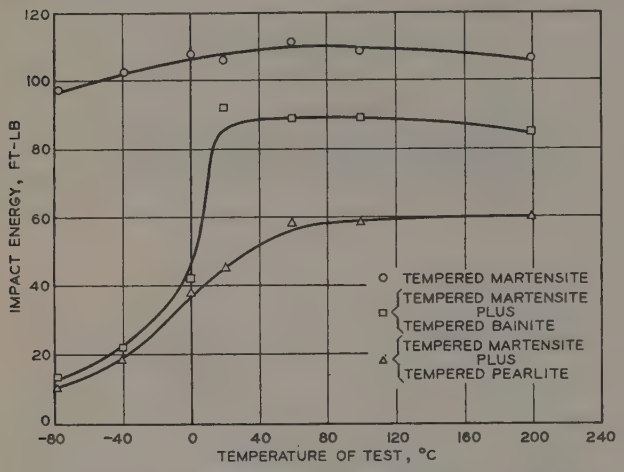


Fig. 3—Effect of Structure on Low-Temperature Charpy Impact Resistance of SAE 8735 at Tensile Strength of About 125,000 Psi

From Transactions of the ASM, Vol. 38, 1947, pp. 807–847: "Effect of Microstructure on Mechanical Properties of Steel" by J. H. Hollomon, L. D. Jaffe, D. E. McCarthy, and M. R. Norton.

Ferrite, as represented by low-carbon constructional steels such as Armco Iron, Izett, and so forth exhibits a characteristic transition lower temperature, has both a fairly wide range in impact resistance at room temperature and a transition temperature range which are sharply affected by the method of manufacture.

Influence of Arrangement of Structural Components

Grain Size—For a given strength level, fine-grained steels generally possess higher notched-bar impact properties than coarse-grained steels at room temperature, and transition temperatures are higher as grain size increases. See Fig. 4.

The fine-grained condition is generally traceable to a specific melting practice which makes use of such additions as silicon-aluminum, vanadium and zirconium.

Size and Shape of Individual Components—Lamellar and spheroidal forms of carbide have a noticeable effect on the shape of the temperature-impact resistance curve. In the case of the former, the values for impact decrease rapidly in the transition zone; spheroidal structures on the other hand show a much less rapid decrease in the transition zone. The transition temperature will, in general, be lower for the spheroidal structures than for the lamellar. Lamellar structures differ among themselves in that the coarser lamellae are more notch sensitive than fine-lamellar structures.

Distribution of Individual Components—Ferritic precipitation in grain boundaries in wrought steel lowers notched-bar tough-

[4] See Transactions of the ASM, Vol. 38, 1947, pp. 807–847: "Effect of Microstructure on Mechanical Properties of Steel" by J. H. Hollomon, L. D. Jaffe, D. E. McCarthy, and M. R. Norton.

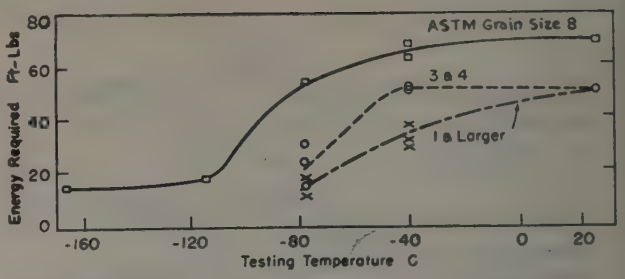


Fig. 4—Effect of Grain Size on Energy Required for Fracture at Various Temperatures of SAE 8640 Steel at Rockwell C34

From Transactions of the ASM, Vol. 40, 1948, pp. 809–811: Discussion by L. D. Jaffe and J. F. Wallace of paper "Influence of Metallurgical Factors on the Mechanical Properties of Steel" by S. A. Herres and C. H. Lorig.

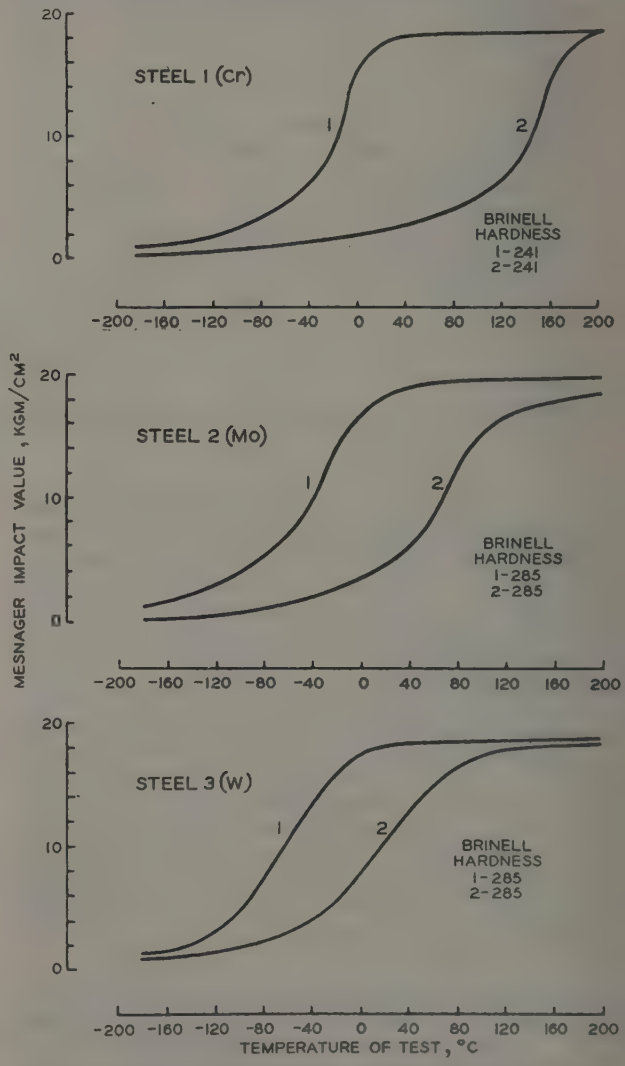


Fig. 5—Effect of Temper Brittleness on Notched-Bar Impact Properties of Steel

State 1: tempered at 650C, quenched 1 hr in water.

State 2: tempered at 650C, quenched 1 hr in water, 525C, 24 hr in water.

From Revue de Metallurgie, Vol. 42, 1945, p. 151: "Sur la fragilité de revenue des aciers au Chrome, au Molybdène, au Tungstène" by Georges Vidal.

[a] TABLE 1—*Effect of Silicon on Physical Properties of Cast Carbon and Carbon-Molybdenum Steels*

COMPOSITION, %						PHYSICAL PROPERTIES (NORMALIZED 1750 F, DRAWN 1250 F)						
C	Mn	Si	S	P	Mo	Tensile strength, psi	Yield point, psi	Elongation, % in 2 in.	Reduction of area, %	Hardness, VPN	Charpy impact (keyhole notch) ft-lb at room temperature	Charpy impact (keyhole notch) ft-lb at—25 F
0.29	0.69	0.35	0.032	0.019	—	72,200	40,600	40.0	52.0	148	21.3	15.8
0.28	0.58	0.60	0.021	0.018	—	75,500	42,500	31.0	46.0	161	21.8	16.3
0.25	0.60	1.43	0.028	0.021	—	88,500	51,000	29.0	48.0	177	13.8	9.0
0.25	0.69	2.04	0.032	0.020	—	95,000	54,000	28.0	47.0	201	5.3	2.5
0.26	0.60	0.39	0.022	0.022	0.48	75,500	48,000	29.0	48.0	158	26.8	21.8
0.28	0.62	0.68	0.028	0.019	0.59	88,800	62,300	26.5	51.0	182	23.5	—
0.27	0.66	0.81	0.023	0.022	0.45	87,500	58,000	30.0	48.0	191	25.3	18.3
0.23	0.55	1.40	0.023	0.020	0.58	94,000	57,000	29.0	45.0	200	15.3	3.0
0.26	0.55	1.92	0.026	0.020	0.49	92,600	56,600	29.0	46.0	201	6.8	2.3

[a] From ASM preprint No. 18 for meeting Oct. 25-29, 1948: "The Effect of Vanadium on the Properties of Cast Carbon and Carbon-Molybdenum Steels" by N. A. Ziegler, W. L. Meinhart, and J. R. Goldsmith.

ness appreciably. Sufficient evidence is at hand to say that certain constituents, whether ductile or brittle in themselves, occurring in a continuous or network arrangement can have a deleterious affect on toughness and notch sensitivity at low temperatures.

Heat-Treatment—From the information available as to the most desirable conditions for producing good impact properties at low temperatures, it would seem that the austenitizing treatment should aim at complete solution and that the quench should be carried out so that complete transformation to martensite is approached as nearly as possible. The steel should have been selected to allow the use of as high a tempering temperature as possible. Steels containing strong carbide formers such as chromium, molybdenum, and vanadium show strong tendencies for the precipitation of carbide in certain temperature ranges. In setting up tempering temperatures, these ranges must be avoided and a higher temperature used to produce good notched-bar impact resistance. The critical temperature for chromium steels is approximately 900 F, for molybdenum steels 1000 F, and for vanadium steels may reach 1100 F.

Temper brittleness is sometimes responsible for low impact resistance in medium- and high-alloy steels. Quenching from tempering temperatures above approximately 1100 F will avoid the effects of temper brittleness almost entirely. Temper brittleness raises the transition temperature. (See Fig. 5.)

Strain aging raises the transition temperature. The increase in transition temperature is proportional to the amount of cold work. Fine-grained fully killed steels are much less susceptible than coarse-grained steels.

Influence of the Various Elements in Steel

Carbon—Increasing the carbon content for a steel of a given base composition, in general, causes a rapid decrease in room-temperature notched-bar impact results and tends to increase the temperature of transition or embrittlement. Although the nonheat-treated steels are sensitive to carbon content, for the quenched-and-tempered steels in the medium range of carbon, the carbon content is not so critical.

Manganese—Manganese content up to about 1.5% has a beneficial influence on the low-temperature embrittlement of low-carbon and medium-carbon steels, but larger quantities are detrimental. At higher carbon contents, manganese increases the hardness of pearlitic steels, which results in lower impact values (a structural, not temperature, effect).

Silicon—Mild steels deoxidized with small amounts of silicon have a finer ferritic grain and lower transition temperature than similar steels of the rimming type. The effect of silicon in quantities somewhat greater than that required for deoxidation is to raise the transition temperature. This effect of silicon in reducing the low-temperature impact resistance of steel has been demonstrated in carbon and alloy steels over the entire range of microstructure from martensite to pearlite.[5, 6] See Table 1.

Sulfur and Phosphorus—Sulfur in the normally encountered

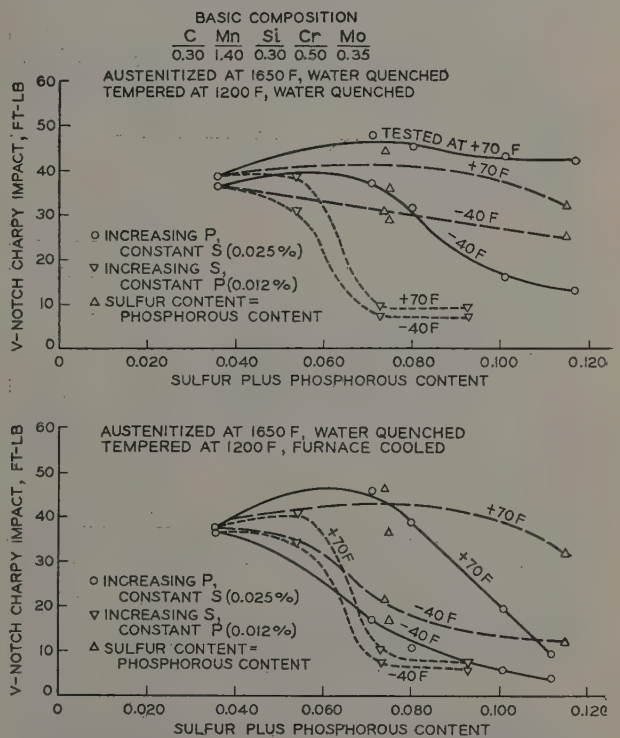


FIG. 6—INFLUENCE OF SULFUR AND PHOSPHORUS, SEPARATELY AND IN COMBINATION, UPON THE NOTCHED-BAR IMPACT PROPERTIES AT +70 AND −40 F

From unpublished data from the files at Watertown Arsenal, Watertown, Mass.

[5] See ASM preprint No. 18 for meeting Oct. 25-29, 1948: "The Effect of Vanadium on the Properties of Cast Carbon and Carbon-Molybdenum Steels" by N. A. Ziegler, W. L. Meinhart, and J. R. Goldsmith.

[6] Unpublished data from the files at Watertown Arsenal, Watertown, Mass.

ranges has not been proved to affect the low-temperature impact properties of wrought carbon steels. However, in the higher ranges of sulfur together with higher carbon, especially in cast steels, there are some data to support the conclusion that sulfur is detrimental (Fig. 6).

The effect of increasing phosphorus contents upon the notched-bar impact resistance of steel is to raise progressively the temperature of transition from ductile to brittle behavior, as shown in the upper series of curves of Fig. 7.

In applications where low-temperature impact resistance is of importance, it is advisable to keep the sulfur low and the phosphorus content of quality steels at a minimum.

Chromium—Chromium as an alloying element in low-alloy steels promotes increased hardenability which is associated with improved structures in such steels, which without chromium are not full hardening. Such improvements in structure are associated with improved low-temperature impact qualities. Chromium is an essential element in low-carbon stainless steels, which are extremely useful materials because of their relative insensitiveness to low-temperature embrittlement.

Molybdenum—Molybdenum in usual quantities acts similarly to chromium in promoting improved structures in low-alloy steels. As such, it promotes improved low-temperature impact properties and in addition tends to minimize temper brittleness.

Nickel—Nickel is beneficial in maintaining toughness at subnormal temperatures. It is commonly used in percentages up to about 8½% in wrought ferritic products and up to 5% in cast ferritic products, depending on the temperature environment. Typical results of notched-bar tests are illustrated in Fig. 8.

In common with other low-alloy steels, the nickel-bearing low-alloy steels develop their greatest resistance to low-temperature embrittlement in the quenched-and-tempered condition.

Nickel is also used in larger percentages in various alloys which are austenitic. These austenitic materials have very good low-temperature toughness, in either the cast or wrought form.

Copper—Available data indicate that copper in solid solution is mildly beneficial, whereas in the age-hardened or precipitated state it has an adverse effect on low-temperature ductility. Copper-bearing steels, when welded and stress relieved may often be embrittled by age hardening.

Vanadium—The effect of vanadium on Charpy impact re-

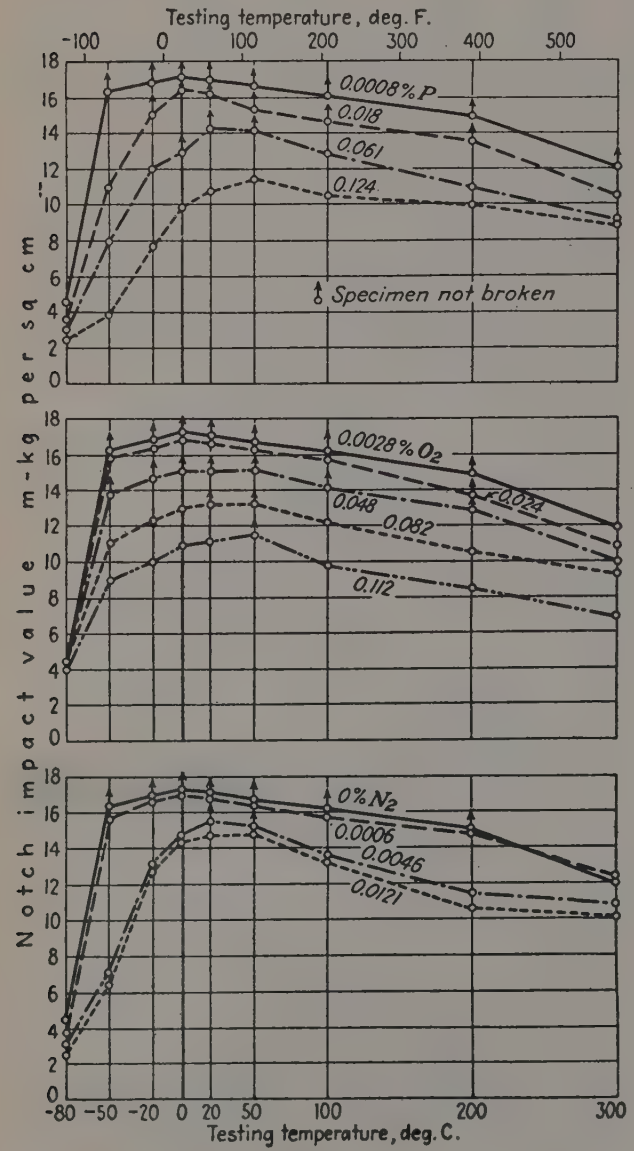


FIG. 7—EFFECT OF PHOSPHORUS, OXYGEN, AND NITROGEN ON THE HIGH-TEMPERATURE AND LOW-TEMPERATURE IMPACT RESISTANCE OF HIGH-PURITY INGOT IRON

From page 468 of "Alloys of Iron and Carbon, Vol. II, Properties," by F. T. Sisco. Published by McGraw-Hill Book Co., Alloys of Iron Monograph Series, New York, 1937.

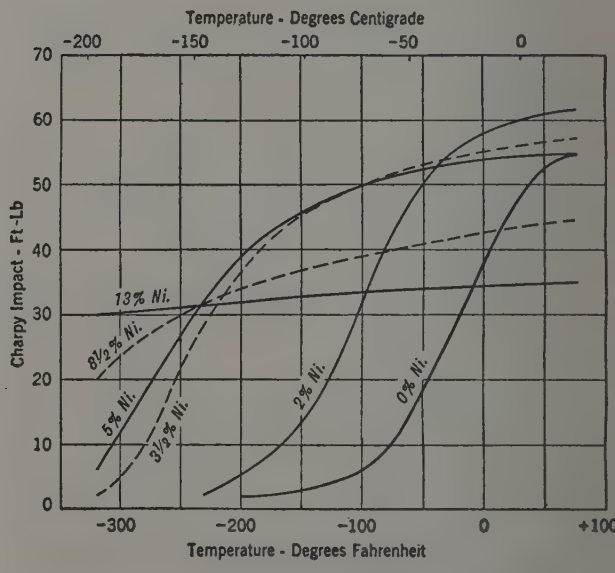


FIG. 8—EFFECT OF NICKEL CONTENT ON THE RESISTANCE TO LOW-TEMPERATURE EMBRITTLEMENT OF NORMALIZED LOW-CARBON STEELS

Charpy keyhole-notch specimens used. All steels contain 0.10% C except the 2%-Ni steel, which contains 0.15% C.

From "Some Properties of Low-Carbon 8½ Per Cent Nickel Steel," by T. N. Armstrong and G. R. Brophy. Paper presented before ASME Conference on Petroleum Mechanical Engineering Oct. 5-8, 1947.

[a]TABLE 2—*Effect of Vanadium on Impact Resistance of Commercial Manganese Cast Steel at Low Temperatures*

HEAT NO.[b]	COMPOSITION, %						YIELD POINT, PSI	TENSILE STRENGTH, PSI	ELONGATION, % IN 2 IN.	REDUCTION OF AREA, %	RATIO OF YP TO TS	IZOD, FT-LB	CHARPY[c] (KEYHOLE NOTCH), FT-LB						VICKERS (30 KG)	HEAT NO.[b]
	C	Mn	Si	S	P	V							at 70 F	at 0 F	at −25 F	at −50 F	at −75 F	at −90 F		
A	0.30	1.70	0.40	0.016	0.030	—	65,550	102,350	25.6	57.3	0.64	29.5	25.0	21.5	17.7	3.0/10.5	—	—	215	A
B	0.31	1.65	0.38	0.017	0.028	0.10	79,180	104,000	25.6	58.4	0.76	67.0	40.0	33.2	30.0	25.5	24.0	22.5	203	B

[a] Unpublished data from the files of the Vanadium Corp. of America.
[b] Heat-treatment (commercial): 1650 F (2 hr) air + 1500 F (½ hr) air + 750 F (3 hr) air.
Section size: 1¼ in.
[c] Average of three tests.

[a]TABLE 3—*Effect of Vanadium on Impact Resistance of Double Normalized and Tempered Wrought Low-Carbon 4 to 8% Nickel Steels at Low Temperatures*[6]

HEAT NO.[b]	COMPOSITION, %					ALUMINUM ADDITION, %	CHARPY[c] (KEYHOLE NOTCH), FT-LB				VICKERS (30 KG)
	C	Mn	Si	Ni	V		at 70 F	at −250 F	at −300 F	at −320 F	
A	0.13	0.25	0.16	4.06	—	none	43.8	2.7	1.0	—	156
B	0.12	0.29	0.24	4.00	0.32	0.07	86.2	—	31.6	22.5	180
C	0.11	0.29	0.25	6.20	—	0.07	56.0	—	21.8	19.3	180
D	0.11	0.27	0.21	5.75	0.29	0.07	64.2	—	41.2	38.3	204
E	0.11	0.28	0.20	7.81	—	0.07	52.0	—	28.7	4.5/26.5	204
F	0.12	0.23	0.24	7.82	0.29	0.07	52.8	—	40.3	34.6	232

[a] Unpublished data from the files of the Vanadium Corp. of America.
[b] Furnace type: 35-lb laboratory induction furnace heats.
Section size: ½ in.
[c] Average of three tests.

[a]TABLE 4—*Effect of Columbium on Impact Resistance of Wrought SAE 1340 at Low Temperatures*

HEAT NO.[b]	COMPOSITION, %					Cb ADDITION	ASTM GRAIN SIZE	CHARPY[c] (KEYHOLE NOTCH), FT-LB						VICKERS (30 KG)
	C	Mn	Si	Al	Cb			at 70 F	at 25 F	at 0 F	at −25 F	at −50 F	at −75 F	at −90 F
								1575 F (1 hr) Air + 1200 F (2 hr) Air						
A	0.39	1.78	0.18	0.003	none	none	3–5, few 6	19.3	16.7	16.7	3.0	2.3	2.0	1.0	207
B	0.38	1.65	0.26	0.001	0.03	0.05	5–7	38.3	30.5	28.3	22.5	19.3	20.5	2.0/17.5	198
C	0.39	1.78	0.30	0.005	0.08	0.10	6–8	34.3	29.7	28.8	24.8	21.3	18.8	4.5/18.5	206
D	0.39	1.72	0.31	0.004	0.12	0.15	6–7	37.3	33.2	30.0	25.0	25.3	21.8	20.0	196
E	0.38	1.69	0.34	0.005	0.17	0.20	6–7	38.7	31.2	28.2	26.0	23.8	—	20.0	199

[a] Unpublished data from the files of the Vanadium Corp. of America.
[b] Heat-treatment: 1575 F (1 hr) air + 1200 F (2 hr) air.
Furnace type: 35-lb laboratory induction furnace heats.
Section size: ⅝ in.
[c] Average of three tests.

sistance, at low temperatures, of pearlitic manganese cast and wrought steel in the normalized-and-tempered condition and in low-carbon 4 to 8% nickel-plate steels is shown in Tables 2 and 3.

Columbium—The effect of 0 to 0.17% columbium on the low-temperature Charpy impact resistance of a single-normalized and tempered wrought SAE 1340 is shown in Table 4. Available data indicate that addition of small percentages of columbium are generally beneficial but higher quantities may be distinctly detrimental, and as a result the use of columbium should be approached with caution.

Aluminum—The low-temperature Charpy impact resistance of a number of aluminum-treated cast steels is given in Table 5. The addition of aluminum improves the impact resistance of the silicon-dioxidized steel and shifts the transition to lower temperatures. The relatively fine ferritic grain size usually found in aluminum-treated cast and wrought steels contributes largely to the improved low-temperature impact resistance.

Titanium—Fig. 9 shows the effect of 0 to 4 lb of titanium per ton of steel as metallic titanium on the low-temperature Charpy impact resistance of wrought SAE 1030 steel in the as-normalized condition; similar effects have been observed with cast steels. Titanium in small amounts is beneficial. However, larger quanti-

[a]TABLE 5—*Effect of Aluminum on Impact Resistance of Various Cast Steels at Low Temperatures*

TYPE CAST STEEL[b]	ALUMINUM ADDITION, LB/TON	CHEMICAL COMPOSITION, %							GRAIN SIZE	TYPE INCLUSION	HEAT TREATMENT
		C	Mn	Si	S	Cu	Ni	Al			
C	Si	0.27	0.26	0.33	0.026	—	—	—	6	I	1625 F N + 1200 F Air
C	1.5	0.31	0.66	0.38	0.033	—	—	0.053	7	III	1625 F N + 1200 F Air
Med. Mn	Si	0.31	1.55	0.42	0.036	—	—	—	5	I	1575 F N + 1200 F Air
Med. Mn	0.4	0.31	1.56	0.42	0.039	—	—	0.011	7	II	1575 F N + 1200 F Air
Med. Mn	1.5	0.29	1.49	0.42	0.037	—	—	0.038	9	III	1575 F N + 1200 F Air
Med. Mn	4.0	0.32	1.30	0.39	0.030	—	—	0.120	9	III	1575 F N + 1200 F Air
Ni	Si	0.28	0.65	0.38	0.003	—	1.54	—	6	I	1575 F N + 1200 F Air
Ni	1.5	0.30	0.68	0.36	0.041	—	1.55	0.040	8	III	1575 F N + 1200 F Air
Cu-Mn	Si	0.16	1.00	0.97	0.033	1.67	—	—	7	I	1600 F N + 1000 F Air
Cu-Mn	1.5	0.19	0.89	0.81	0.035	1.67	—	0.030	8	III	1600 F N + 1000 F Air

TYPE CAST STEEL[b]	YIELD POINT, PSI	TENSILE STRENGTH, PSI	ELONGATION, % IN 2 IN.	REDUCTION OF AREA, %	ROCKWELL B	CHARPY (V-NOTCH), FT-LB							
						at 75 F	at 32 F	at 0 F	at −20 F	at −40 F	at −60 F	at −80 F	at −100 F
C	40,250	70,500	33.0	47.8	71	30.8	18.0	6.8	5.3	3.0	—	—	—
C	47,500	75,750	25.0	44.1	78	33.8	18.0	11.0	10.0	6.8	5.3	—	—
Med. Mn	65,750	92,500	30.0	55.1	88	20.7	12.3	4.5	2.5	3.3	2.0	1.0	—
Med. Mn	65,500	93,250	26.5	46.0	88	25.0	15.0	10.0	6.7	5.3	3.5	3.3	—
Med. Mn	65,500	91,750	31.0	57.3	88	46.8	48.7	33.3	23.3	20.5	16.3	13.5	9.5
Med. Mn	59,000	87,750	28.5	52.8	84	44.3	26.7	21.3	19.3	12.3	10.8	8.8	6.3
Ni	48,500	78,000	31.0	49.3	78	30.5	19.7	15.5	11.5	7.3	4.5	—	—
Ni	50,000	77,000	32.0	56.3	80	33.5	24.7	16.3	10.3	11.3	5.0	—	—
Cu-Mn	91,000	118,250	23.0	56.0	98	14.5	10.3	8.3	7.3	3.7	2.3	—	—
Cu-Mn	85,750	103,500	23.0	50.6	96	29.3	19.0	13.3	11.7	10.0	7.7	5.7	3.7

[a] From Transactions of the American Foundrymen's Association, Vol. 54, 1946, pp. 357–375: "Low Temperature Properties of Cast Steels" by C. E. Sims and F. W. Boulger
[b] Furnace type: Laboratory induction.

ties may be detrimental and should be avoided in carbon and low-alloy steels.

Zirconium—Fig. 10 shows the effect of zirconium additions (0 to 4 lb per ton) as silicon-zirconium alloy on the low-temperature Charpy impact resistance of wrought SAE 1030 steel. Optimum results on these steels were obtained with about ½ to 1 lb zirconium per ton of steel.

Nitrogen—The effect of nitrogen on the high- and low-temperature notched-bar properties of high-purity ingot iron is shown in Fig. 7. The effect of increasing nitrogen content in the iron is to raise progressively the temperature of transition from ductile to brittle behavior.

Oxygen—Increasing concentrations of oxygen, like increasing amounts of nitrogen, in high-purity ingot iron raise the temperature of transition from ductile to brittle behavior, as is shown in the middle series of curves of Fig. 7. The embrittling effect of oxygen in steel and iron is modified perceptibly by the presence of strong deoxidizers which combine with the oxygen to form inert inclusions.

Hydrogen—The effect of hydrogen on the embrittlement of steel and iron at low temperatures appears not to have been determined.

Design Factors Affecting Low-Temperature Behavio of Ferrous Materials

In relating the elements of design to low-temperature service particular attention must be paid to stress raisers such as notches sharp fillets, and rapid change in section. The conditions in themselves increase stress and indicate probability of fracture a lower loads than would be the case if stress raisers were absent Low-temperature service brings into play the characteristics o the material itself, and the increased hardness of the steel at lo temperatures tends to raise the resistance to local deformatio in the vicinity of the notch. The latter increases the stress-con centrating power of the notch. When parts intended for low temperature applications are to be heat-treated, the design shoul be modified to avoid quench cracking and excessive distortion The residual stresses from heat-treatment may at times b favorable and at other times be unfavorable to the retention o ductility at low temperatures.

Heavy sections should be avoided wherever possible becaus of the difficulty in obtaining the desired microstructure. Larg masses of metal tend to increase the restraint on local deforma tion, thereby promoting brittle fracture. Higher-strength ma

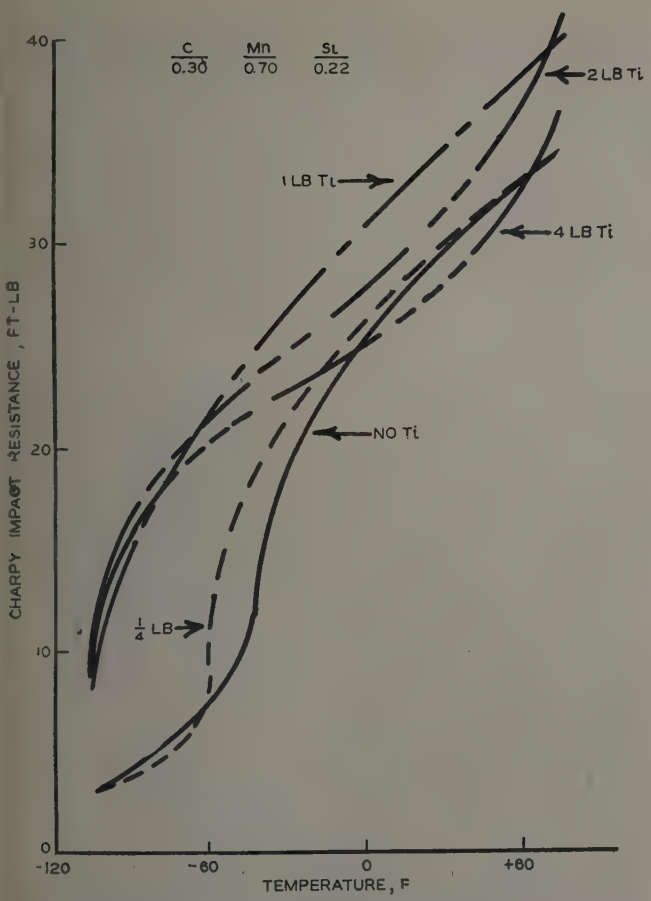


FIG. 9—EFFECT OF TITANIUM ON LOW-TEMPERATURE CHARPY IMPACT RESISTANCE OF WROUGHT CARBON STEEL NORMALIZED AT 1600 F

From unpublished data from the files of the Vanadium Corp. of America.

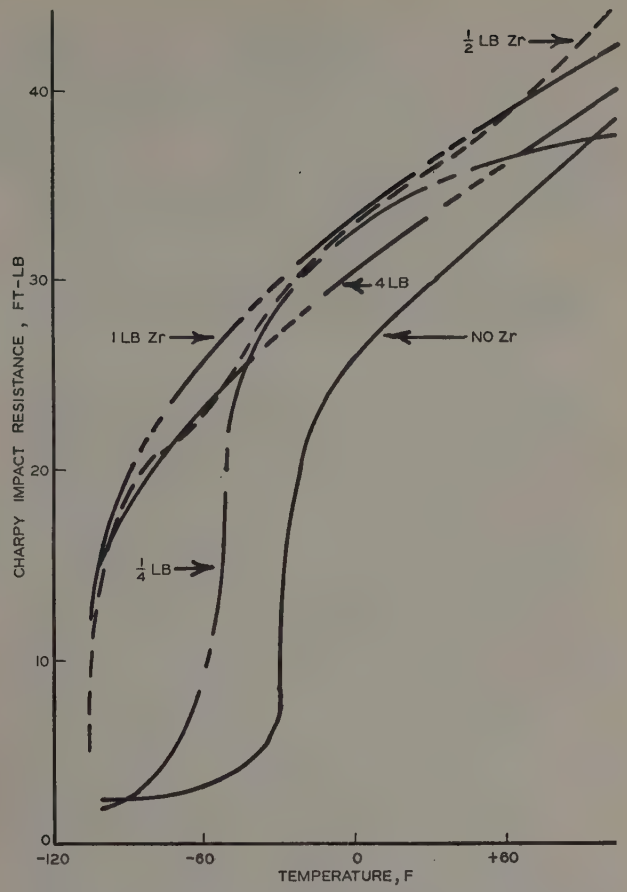


FIG. 10—EFFECT OF ZIRCONIUM ON LOW-TEMPERATURE CHARPY IMPACT RESISTANCE OF WROUGHT SAE 1030 NORMALIZED AT 1600 F

From unpublished data from the files of the Vanadium Corp. of America.

terials in thinner sections should be used wherever possible.

Carburizing, nitriding, and shot peening produce fundamentally similar surface conditions in that each develops a shell of relatively high hardness and low ductility and toughness. Compressive stresses of varying degree result depending upon the depth of the effect. The hard material produced by these treatments is highly notch sensitive at room temperature, and low-temperature service will accentuate this condition. Surface imperfections such as scratches and tool marks and stamped-in numbers have a deleterious effect at room temperature, which will be accentuated at low temperatures.

Selection of Steel for Low-Temperature Service

From the above, it is apparent that no set rule exists to govern the selection of a steel for a particular low-temperature application. The variables are so manifold that each part must be considered separately on the basis of the following factors:

1. Type and distribution of stress.
2. Rate of strain.
3. Specific temperature range involved.

In general, the more severe these conditions are, the lower must be the transition temperature of the steel in whatever test may be employed.

It is, therefore, apparent that where the maximum shear stress is high compared to the maximum principal stress, such as in torsion, and the simple tension test under conditions of moderate rate of strain and temperature, steels with higher transition temperatures can be tolerated. Where high strain concentration and high rate of strain, as well as low service temperatures are encountered, it will be necessary to select steels with low transition temperatures.

Service at Room Temperature to −25 F—For most applications it is probable that plain carbon steel will be satisfactory. In the lower part of this range where the service involves high stress concentration and high rates of strain, the selection of fully killed steels in place of rimmed or semi-killed steels is justified.

Service at −25 to −100 F—At temperatures below −25 F,

TABLE 6—*Low-Temperature Notched-Bar Properties of Certain Chromium-Nickel Austenitic-Type Steels*

TYPE OF STEEL	COMPOSITION, %				CONDITION[c]	TYPE SPECIMEN	NOTCHED-BAR IMPACT VALUES			
	C	Cr	Ni	Mo			F	ft-lb	F	ft-lb
30302 Wrought[a]	0.11	16.2	11.5	—	WQ at 2010 F	Izod V-notch	−85	118	−292	118
30302 Wrought[a]	0.09	18.51	9.65	—	A at 1900 F	Izod V-notch	−110	113	−300	119
30304 Wrought[a]	0.07	17.14	8.24	—	A, CD	Izod V-notch	−110	68	−300	65
30316 Wrought[a]	0.07	18.41	9.88	2.80	A, CD	Izod V-notch	−105	77	−300	80
30302 Cast[b]	0.07	19.0	9.5	—	A	Charpy keyhole notch	75	75	−150	64
							−320	57	−423	52

[a] Information taken from ASM Metals Handbook, 1948 Edition, p. 210, Table XVI.
[b] Unpublished information from Lebanon Steel Foundry, Lebanon, Pa.
[c] WQ = Water quenched.
A = Annealed.
CD = Cold drawn.

the designer is likely to change from plain-carbon steels to alloy steels. Within the range −25 to −100 F, most martensitic steels have either reached their transition temperature or begin to decrease in impact values, indicating that higher stress concentrations in structural parts than those present in notched bars might cause brittle failures.

Because of the grouping of such a large number of steels in this 75-degree temperature range, based on the results of the notched-bar values, there is quite naturally an overlap of transition zones and variation of transition zones throughout the entire range. This extreme overlapping and also wide scatter makes it impossible to separate steels into groups having comparable notched-bar results over 25-degree temperature increments. Because of this fact, the separation of steels for use in structural parts within this temperature range is also impossible and probably will continue to be until much additional knowledge of the temperature effect is gained. A discussion of some of the methods and opinions relative to design for use in the −25 to −100 F temperature range is, therefore, all that is possible on the basis of present knowledge.

One method of eliminating questionable steels for use at low temperatures would be to discard those known to be subject to temper brittleness on tempering or on slow cooling. Such steels include the SAE 1300, SAE 3100, SAE 3300, SAE 5100, and SAE 6100 series. Some steels that are not appreciably subject to temper brittleness are the SAE 2300, SAE 4000, SAE 4100, SAE 4300, SAE 4600, SAE 8600, and SAE 8700 series and would be safer selections if doubts relative to other steels existed.

In view of the previous discussion and remembering that the following is only a very broad generality, it can be stated that plain low- and medium-carbon steels may be usable to −50 F or even lower in some cases, and low-alloy, low-carbon steels, and the standard SAE alloy steels are usable to temperatures of −100 F and below. These remarks apply only to steels made under the best practice as outlined under other sections of this report.

Service from −100 F to −200 F—Certain ferritic steels exhibit acceptable impact properties in this range, but detailed consideration must be given to melting practice, heat-treatment, and subsequent thermal treatment such as stress relief and welding. If low-carbon alloy steels are used, a liquid quench should be used to get the best properties of tempered martensite. Most of the common austenitic stainless steels can be used; see Table 6.

Service at −200 F and Below—At these low temperatures, only normalized-and-tempered, and quenched-and-tempered low-carbon alloy steels of the nickel, nickel-molybdenum, chromium-molybdenum, and manganese-molybdenum varieties are recommended besides the austenitic stainless alloys. If ferritic steels are employed for highly stressed parts, the most careful attention to detail is required in their processing. Stress-relieving treatments must be applied with caution, and only those welding techniques and materials which have been carefully proved should be utilized.

Present experience indicates that the austentic stainless steels will be generally employed for service at temperatures below −200 F. Their impact properties remain excellent if the nickel and chromium and minor elements are adjusted to yield a completely or substantially austenitic low-carbon alloy. If these precautions are taken, there appears to be little variation in properties from heat to heat if proper quench annealing is applied.

At these very low temperatures, great care must be taken in the application of welding and other types of post heat-treatments. The type of electrode coating becomes important if impact properties comparable to the base metal are to be retained in the weld deposit and interface zone.

Selection of Materials other than Steels for Low-Temperature Service

Cast iron appears to perform at low temperature and room temperature in much the same manner. Experimental data are insufficient for a more detailed statement.

Pearlitic malleable is somewhat inferior to standard malleable in low-temperature impact properties. The standard malleable irons show some variation among themselves which can, at times, be traced to differences in microstructure. In the unnotched condition, both have high impact values and appear to be relatively insensitive to temperature effects down to −80 F.

Nickel-base alloys of the Monel and Inconel types, as well as others, increase in strength at low temperatures without serious loss in ductility.

Method of Determining Hardenability of Steels

SAE Recommended Practice

Report of Iron and Steel Division approved January 1942 and last revised by Iron and Steel Technical Committee January 1951.

[*This SAE Recommended Practice prescribes the procedure for making hardenability tests and recording results. Also included are charts*[1] *for plotting hardenability-test results and for predicting hardness U curves in various sizes of rounds.*

For routine testing of the hardenability of successive heats of steel required to have hardenability within certain limits, it is sufficient to designate hardenability simply in terms of distance from the quenched end to the point at which a certain hardness is obtained. This designation is also adequate for comparing steels of different compositions to see whether they have similar hardenability.

Hardenability limits for specifying steel in this manner are obtained by measuring the hardenability of a steel which has proved satisfactory for the use intended. The hardenability test may be used in this way as an empirical test. If no other use of hardenability data is contemplated, there is no need to know what cooling rates during quenching are responsible for the different hardnesses obtained along the hardenability test bar.

A very important additional use of hardenability data, however, is the prediction of hardnesses obtainable with any steel in new machine parts not yet in production and not similar to any parts on which production experience is available. To make such a prediction, it is necessary to know the cooling rates occurring in the part during quenching.

There are three methods of gettng information as to what these cooling rates are:

1. They may be measured by thiermocouples. This method requires special equipment.

2. They may be estimated by making the part of some steel, determining the hardness after quenching, and then substituting cooling rates for corresponding hardnesses from a hardness-cooling rate curve for the same steel obtained from a Jominy hardenability test.

3. They may be approximated by comparing the different sections of the part with round or plate sections of similar size on which cooling rates have been determined.

Method 1 has been described in an SAE Journal article[2]. *(The article also traces the steps in the selection of steel for a gear by means of an analysis of cooling rates in the gear and hardenability curves for steel.*

Method 2 is sometimes referred to as the substitution-of-cooling-rate-for-hardness method.

Method 3 is in most cases sufficiently accurate to provide enough information for deciding how much hardenability is required in a steel for the part in question. The hardnesses at various depths below the surfaces of rounds can be plotted for any steel for which a Jominy hardenability curve has been obtained. Curves for making the conversion are given in Fig. 14. The hardness obtained from the hardenability curve may be substituted at the location in the round bar having the same cooling rate. This method may be used to produce the hardness U curve for any section size covered by the chart. The U curves are then useful for indicating what hardness to expect in corresponding section sizes in the machine part under consideration.

Where quenching conditions to be used in production are other than those represented in Fig. 14, Method 2 may be used to determine cooling rates in a simple shape of appropriate section size to represent the section size of the machine part in question.

See also the SAE Standard for Hardenability Bands for H Steels and the SAE Journal series "Selection of Steel for Automobile Parts."[3]]

Test Procedure for One-In. Standard Hardenability Specimen (Fig. 1)—Any hardenability tests made under other conditions than those given in this SAE Recommended Practice will not be deemed standard and will be subject to agreement between supplier and user. Whenever check tests are made all laboratories concerned must arrange to use the same alternate procedure with reference to test specimen (Figs. 2, 3, or 4) and method of grinding for hardness testing (Section *E*).

A. Test Specimen—The test specimen is a 1-in.-diameter cylinder 4-in. long with means for hanging it in a vertical position for end quenching. Fig. 1 shows a test specimen in the fixture ready for quenching illustrating the preferred form of specimen. Figs. 2, 3, and 4 give the details of the preferred specimen and two optional specimens.

The bar from which the specimen is machined shall be a forged rolled 1¼-in. round representing the full cross-section of the product. A cast specimen may be used in lieu of a rolled or forged specimen. That the specimen represent the full cross-section is of primary importance, since any attempt to secure test specimens from any portion of the bloom, billet, or bar other than the full cross-section may introduce factors tending to affect the reproducibility of results. The condition of this hot-formed bar shall be such that there is no decarburization on the 1-in. specimen machined from it.

Optional Specimen Preparation—The following method is satisfactory for most purposes, but for check testing against specifications, the method in the above paragraph is mandatory.

The test specimen shall be machined from the center of the bar in the case of sections from 1¼- to 2-in. round or square. In sections over 2 in., the test specimen shall be machined from one half of the section with the axis of the specimen located at a point halfway between the center and surface of the bar and marked to identify the position of the test bar with reference to the original bar. The hardness readings shall be made on the two sides of the test specimen corresponding to a position in the bar approximately halfway between the center and the surface.

B. Normalizing Prior to Heating for End Quenching—The forged or rolled round shall be normalized prior to machining the test specimen. This is of importance since the structure of material before quenching may materially affect the hardening characteristics. In order that variations in prior structure may

[1] Copies of the Standard Hardenability Chart for L Bar, Fig. 13 of this SAE Recommended Practice, may be obtained at nominal cost from the SAE. Copies of the Standard Form for Plotting Hardenability Curves, Fig. 14, may be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

[2] See SAE Journal, Vol. 52, No. 10, Oct. 1944, pp. 472–485: "Selection of Automotive Steel on the Basis of Hardenability," by A. L. Boegehold.

[3] See SAE Journal, Vol. 57, No. 8–12, and Vol. 58, No. 1, Aug. 1949 through Jan. 1950: "Selection of Steel for Automobile Parts," prepared at the request of the SAE ISTC Div. XVIII—Hardenability Publications. Part I was prepared by Joseph Geschlin and Parts II–VI by A. L. Boegehold.

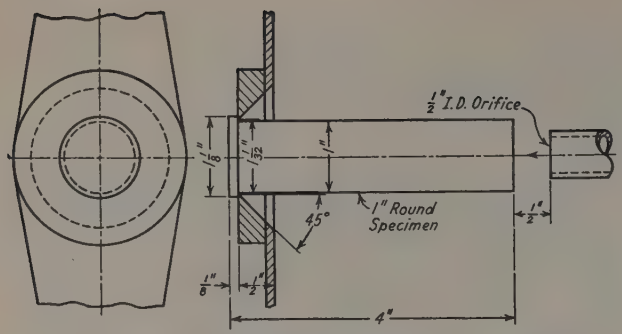


FIG. 1—HARDENABILITY TEST SPECIMEN IN FIXTURE FOR WATER QUENCHING

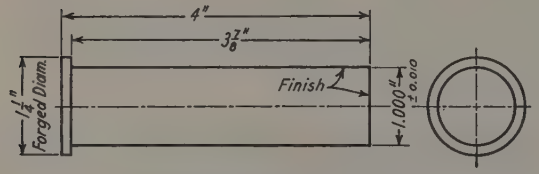


FIG. 2—PREFERRED TEST SPECIMEN

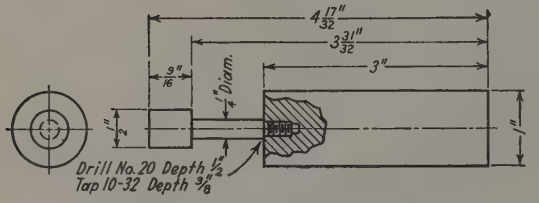


FIG. 3—OPTIONAL TEST SPECIMEN FOR A TEST

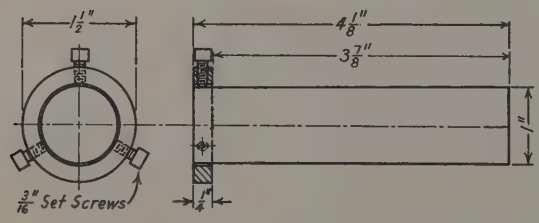


FIG. 4—OPTIONAL TEST SPECIMEN FOR B TEST

be controlled as much as possible, the normalizing temperature listed in Table 1 should be used. The steel shall be held at such temperature for 1 hr and cooled in still air. If the normalized specimen is too hard, it may be given a short time temper at about 100 F below the Ac_1 to improve machinability. The record of hardenability test results must always state the prior thermal history of the specimen tested. (In regard to tool steels, see the first paragraph following the heading "Special Hardenability Test Bars" in this SAE Recommended Practice.)

C. Heating for End Quenching—The specimen shall be heated to the austenitizing temperature shown in Table 1. The specimen shall be placed in a furnace which is at the specified temperature and shall be held at this temperature for 30 min. It is necessary to determine by means of a thermocouple the time required for a test specimen to come to temperature to be sure that the above heating time and temperature requirements are met.

TABLE 1—*Normalizing and Quenching Temperatures*[a] *Applicable to Steel Ordered to End-Quench Hardenability Requirements*

MAXIMUM ORDERED CARBON CONTENT	NORMALIZING TEMPERATURE, F	AUSTENITIZING TEMPERATURE, F
Steel Series 1000, 1300, 3100, 3200, 4000, 4100, 4300, 4600, 5000, 5100, 6100[b], 8600, 8700, 9400, 9700, 9800, 9900		
Up to 0.25 inclusive..	1700	1700
0.26 to 0.36 inclusive..	1650	1600
0.37 and over.....	1600	1550
Steel Series 2300, 2500, 3300, 4800, 9200		
Up to 0.25 inclusive..	1700	1550
0.26 to 0.36 inclusive..	1650	1500
0.37 and over.....	1600	1475
0.50 and over (9200)...	1650	1600

[a] A variation of ±10 F from the above temperatures is permissible.
[b] Normalizing and austenitizing temperatures shall be 50 F higher for the 6100 series.

It is important that while heating the test specimen care be taken that its environment is such that practically no scaling or decarburization takes place on the end to be quenched. An adequately protective atmosphere in the furnace is suitable for meeting the above requirements. In the absence of such atmospheres, the specimen shall be inserted in a suitable container and placed with the bottom end of the specimen resting on a graphite or carbon disc.

Fig. 5 illustrates a type of container which has been used with success. However, any similar type will be satisfactory.

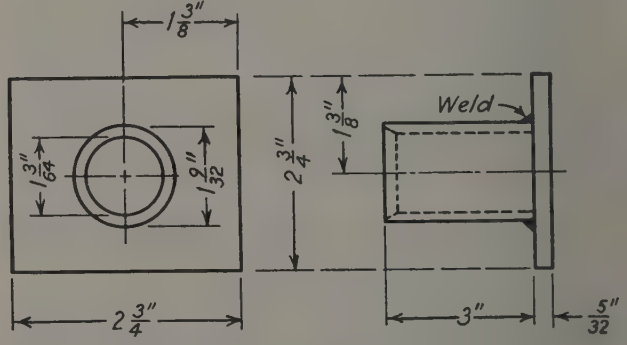


FIG. 5—HARDENING-BAR PROTECTING FIXTURE TO BE CONSTRUCTED OF HEAT-RESISTING ALLOY

D. Quenching—The test piece shall be placed on a fixture so that a column of water at a temperature of 40 to 85 F may be directed against the bottom face of the piece. The column of water passing through an opening ½ in. in diameter shall rise to a free height of 2½ in. above the opening. The fixture shall be dry at the beginning of each test.

In performing the test, the water supply shall be shut off with a quick-opening valve and the hot specimen placed over the water pipe so that the bottom of the specimen is ½ in. from the opening of the water pipe and the water shall then be turned on. The time between removal of the specimen from the furnace and the beginning of the quench shall be not more than 5 sec. The sample shall remain on the fixture for at least 10 min. A

condition of still air shall be maintained around the piece during cooling.

E. Hardness Measurement—Two flats 180 deg apart shall be ground not less than 0.015 in. deep along the entire length of the bar and Rockwell C hardness measurements made along the length of the bar.

The preparation of the two flats must be carried out with considerable care. They should be mutually parallel and the grinding done in such a manner that no change of the quenched structure takes place. Wet grinding is believed to be the only method of controlling the latter condition. In order to detect tempering due to grinding, the flat shall be etched as follows:

Two etchant solutions are used:

No. 1—5% nitric acid (concentrated) and 95% water by volume.

No. 2—50% hydrochloric acid (concentrated) and 50% water by volume.

Wash the sample in hot water. Etch in solution No. 1 until black. Wash in hot water. Immerse in solution No. 2 for 3 sec and wash in hot water. Dry in air blast.

The presence of lighter or darkened areas indicates that hardness and structure have been altered in grinding. All structural changes caused by grinding shall be removed before hardness tests are made. This may be accomplished by resurfacing and again etching, or new flats may be prepared.

As an optional method, the specimens may be centerless ground to 0.970 to 0.965 in. prior to taking hardness readings. Instructions regarding the etching to detect burning or tempering in grinding apply. The V-block used for supporting the specimen must have its centerline exactly under the point of the penetrator and shall have an included angle of 120 deg. The Rockwell tester should be checked against standard test blocks before testing the hardenability bar.

Readings shall be taken in steps of $\frac{1}{16}$ in. for the first 1 in. Distance between readings for the last 2 in. may be at the discretion of the tester. When a flat on which readings have been made is used as a base, the burrs around the indentation shall be removed by grinding unless a fixture is used which has been relieved to accommodate the irregularities due to the indentations.

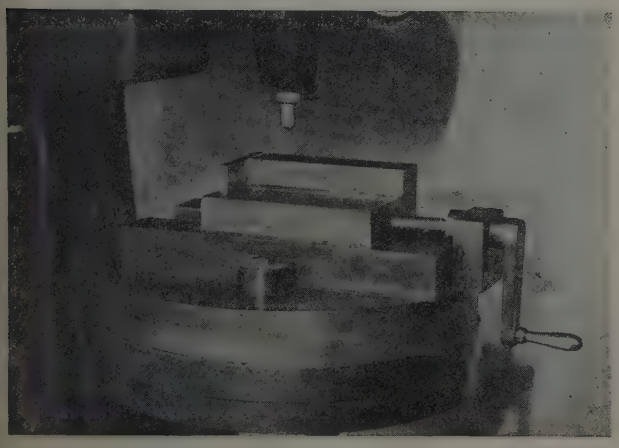


Fig. 6—Anvil

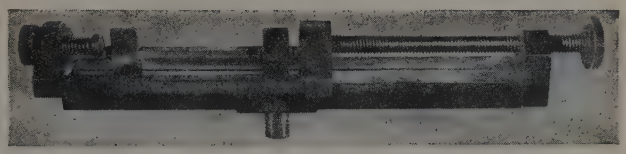


Fig. 7—Anvil

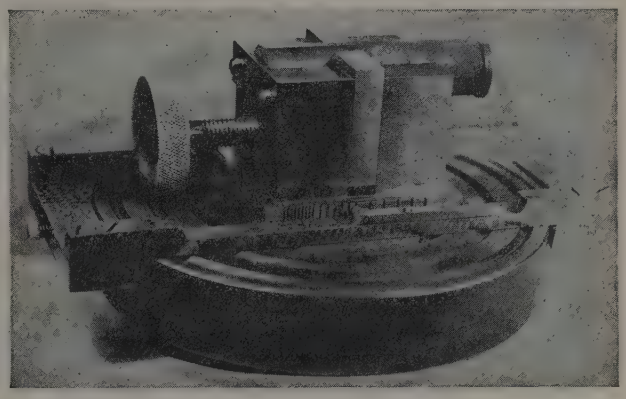


Fig. 8—Anvil

When hardness readings are made, the test specimen rests on one of its flats on an anvil firmly attached to the hardness machine. It is important that no vertical movement be allowed when the major load is applied. It is recommended that the anvil

A. S. T. M. END QUENCH TEST FOR HARDENABILITY OF STEEL (A 255 - 48 T)

DATE_____
LABORATORY_____
TYPE SPECIMEN_____
TEST NO._____

TYPE	HEAT NO.	GRAIN SIZE	C	Mn	P	S	Si	Ni	Cr	Mo		NORM. TEMP. °F.	QUENCH TEMP. °F.

REMARKS:

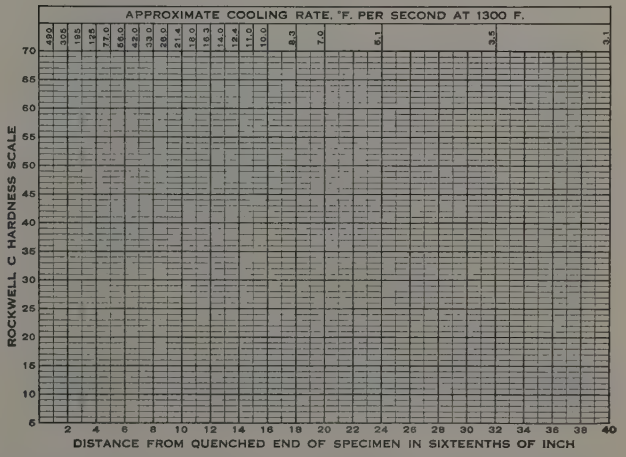


Fig. 9—Standard Form for Plotting Hardenability Curves

Copies of this ASTM chart in 8½ by 11-in. size may be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

be constructed to move the test specimen past the penetrator in accurate steps of 1/16 in. Figs. 6, 7, and 8 illustrate types of anvils which provide for the controlled movement of the test specimen. All have given satisfactory service. The simplest form of this fixture has a 3/8-in., 16-thread screw, to feed the specimen along under the penetrator so that one turn of the screw equals 1/16 in.

Care should be exercised that the registering of the point of the penetrator with the hardened end of the specimen be exact, as well as the subsequent spacing. The methods of plotting results and determining the hardenability index are affected by inaccuracy in these values. After the specimen is accurately aligned with the quenched end, the specimen should be moved over so the first hardness reading is made at the soft end; subsequent readings being made toward the quenched end. This serves to insure seating of the specimen.

F. Plotting of Tests—Tests should be plotted on a standard chart prepared for this purpose (Fig. 9) in which the ordinates represent hardness and the abscissas represent distance from the quenched end. Readings at identical distances should be averaged and the resultant values used for plotting.

Fig. 9 shows the Standard Form for Plotting Hardenability Curves.

Construction of Hardness U Curves—A chart is also provided or using the hardenability curve to predict hardness U curves in various sized rounds when oil or water quenched. Fig. 10

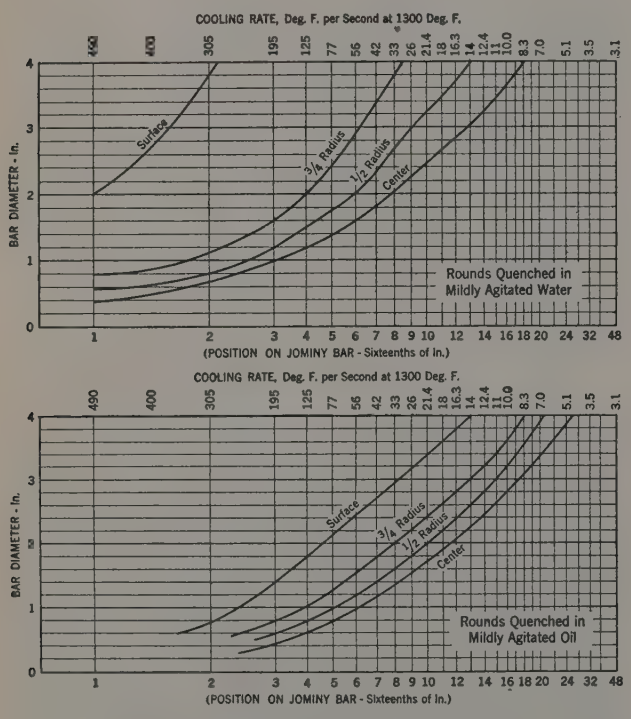

COOLING RATE, Deg. F. per Second at 1300 Deg. F.
490 400 305 195 125 77 56 42 33 26 21.4 18 16.3 14 12.4 11 10.0 8.3 7.0 5.1 3.5 3.1
BAR DIAMETER - In.
Surface
3/4 Radius
1/2 Radius
Center
Rounds Quenched in Mildly Agitated Water
(POSITION ON JOMINY BAR - Sixteenths of In.)
COOLING RATE, Deg. F. per Second at 1300 Deg. F.
490 400 305 195 125 77 56 42 33 26 21.4 18 16.3 14 12.4 11 10.0 8.3 7.0 5.1 3.5 3.1
BAR DIAMETER - In.
Surface
3/4 Radius
1/2 Radius
Center
Rounds Quenched in Mildly Agitated Oil
(POSITION ON JOMINY BAR - Sixteenths of In.)

FIG. 10—CORRELATION OF IDENTICAL COOLING RATES IN JOMINY BAR AND QUENCHED ROUND BARS

These charts have been revised according to corrected cooling rates reported in National Defense Research Committee Report OSRD No. 3743.

shows this chart. The curves show the locations in various sizes of rounds where the cooling rates are the same as at various positions along the end-quenched hardenability test bar.

G. Index of Hardenability—The hardenability of steel may be designated by the use of either one or the other of the two following codes, the first of which is preferred.

1. That code which designates a minimum hardness value at a specified distance from the quenched end. Both minimum and maximum limitations may also be specified in terms of Rockwell C hardness at the required distance from the quenched end.

As an example of this method, a hardenability requirement could be specified as J 36 min = 8/16 or in case of both minimum and maximum restrictions, could be specified as J 36 to 50 = 8/16. This means that at the specified distance of 8/16 in. from the quenched end the Rockwell C hardness should be a minimum of 36 and a maximum of 50.

2. The alternate method would be a code which indicates the distance from the quenched end where the following hardness reference numbers occur. The requirement may be specified as a minimum distance only or as a minimum and a maximum distance at the hardness reference number which applies. Table 2 indicates the hardness reference numbers in terms of Rockwell C values for various carbon contents.

As an example, an alloy steel of 0.34 mean carbon content could be specified to have a hardenability index of J 45 = 4/16 min, which means that the minimum requirements of this steel would be Rc 45 at a distance of 4/16 in. from the quenched end.

If this steel were one having both minimum and maximum curves or limits, the index of hardenability might be specified as J 45 = 4/16 to 11/16.

In addition to the specification in accordance with either of the above two codes, the minimum and maximum hardness at the 1/16-in. position may be specified. These hardness values should be in agreement with the maximum and minimum carbon content specified.

TABLE 2—*Hardness Reference Numbers for Steels of Various Carbon Contents*

MEAN OF ORDERED CARBON RANGE	HARDNESS REFERENCE NUMBER, Rc	
	Alloy steels	Carbon steels
0.08 to 0.17	25	—
0.18 to 0.22	30	25
0.23 to 0.27	35	30
0.28 to 0.32	40	35
0.33 to 0.42	45	40
0.43 to 0.52	50	45
0.53 to 0.62	55	50

Special Hardenability Test Bars—The preceding standard procedure is suitable for steels with less hardening ability than those that harden by aircooling in a 3/4-in. round, excepting some shallow-hardening low-carbon and water-hardening tool steels. For these shallow-hardening steels, other forms of specimens illustrated in Fig. 11 may be used to give more accurate results. Normalizing prior to heating for end quenching does not apply to tool steel which is usually received in the annealed condition. The annealed structure should not be changed prior to heating for the hardenability test.

Fig. 12 shows the cooling rates in these Type L test bars in comparison with the cooling rates in the standard test bar.

(*Continued on next page.*)

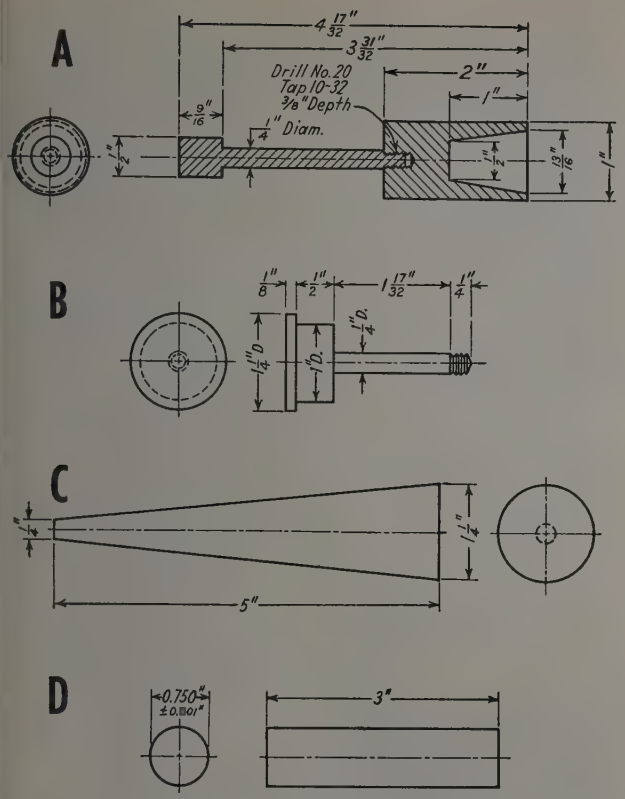


FIG. 11—TEST SPECIMENS FOR SHALLOW-HARDENING STEELS

A—Type L specimen (from ASM Transactions, Vol. 27, pp. 1072–1085: "A Hardenability Test for Shallow-Hardening Steels" by W. L. Jominy).

B—Alternate stud for L-type specimen for use in fixture for standard hardenability bar.

C—Conical specimen (reproduced here for readers' convenience only from SAE Transactions, Vol. 49, July 1941, pp. 278–283: "Determination of Specific Hardenability of Shallow-Hardening Steels" by O. V. Greene and C. B. Post).

D—Shepherd P-F test (reproduced here for readers' convenience only from ASM Transactions, Vol. 22, 1934, p. 979: "The P-F Characteristic of Steel" by B. F. Shepherd).

The L-type specimen, the free water column height should be 4 in. and the orifice ½ in. below the end of the test specimen.

Hardness curves for the Type L test bar should be plotted on the chart shown in Fig. 13.

Sub-Size Test Bars—For determining hardenability of steel received in bars less than 1¼ in. in diameter, the test bar may be made ¾, ½, or ¼ in. diameter, as desired, and end quenched as prescribed for the 1-in. round. Modifications in the water orifice are required for quenching cylinders of less than 1-in. diameter. The details of orifices for quenching specimens less than 1-in. diameter are given in Table 3.

The greater aircooling effect on test bars less than 1-in. diameter and especially in bars smaller than ¾-in. diameter, the cooling rates at various distances from the quenched end will not be the same as in the standard test bar.

Hardness curves from these smaller bars are not comparable with curves from the 1-in. diameter specimen. If the standard hardness curve from sub-size specimens is needed it becomes necessary to make actual cooling-rate determinations on the sub-size specimen in question.

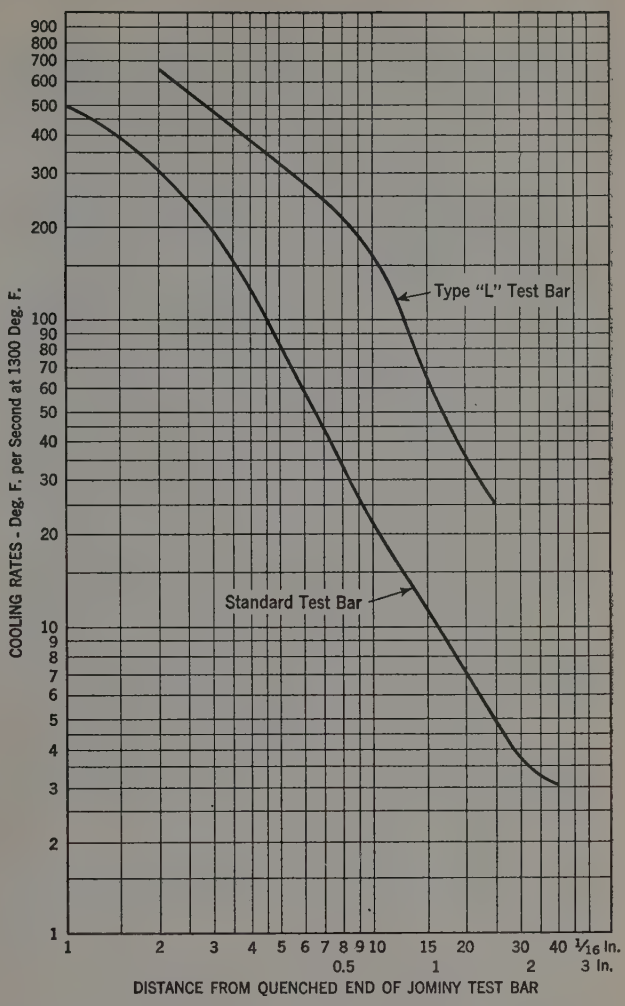


FIG. 12—COOLING RATES AT DIFFERENT DISTANCES FROM THE QUENCHED END OF THE STANDARD TEST BAR AND OF THE TYPE L TEST BAR

Cooling rates for the standard test bar are based on data from National Defense Research Committee Report OSRD No. 3743.

Insert Test Bar for Testing Steel of Small Diameter—For specimens less than ¼ in. in diameter, the insert test bar may be used. As with the sub-size test bars, the results are comparable only with other tests on the same kind of bar. The cooling rates at various distances from the quenched end of test specimens less than 1 in. in diameter have not yet been determined, but it can be stated that due to the proportionate increase in the effect of aircooling as the diameter of the test bar decreases, the curve for cooling rate versus distance from the quenched end in sizes less than 1-in. diameter will not be the same as for the 1-in. diameter.

TABLE 3—*Orifices for Small Quenching Specimens*

TEST BAR DIAMETER, IN.	ORIFICE SIZE, IN.	DISTANCE FROM ORIFICE TO QUENCHED END OF SPECIMEN, IN.	FREE HEIGHT OF WATER COLUMN, IN.
¾	½	½	2½
½	¼	⅜	4
¼	⅛	¼	8

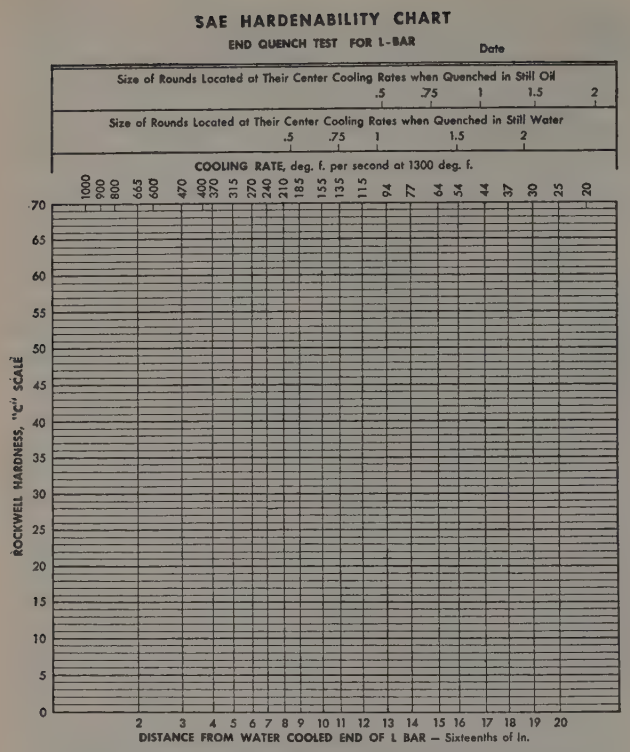

SAE HARDENABILITY CHART
END QUENCH TEST FOR L-BAR
Date
Size of Rounds Located at Their Center Cooling Rates when Quenched in Still Oil
.5 .75 1 1.5 2
Size of Rounds Located at Their Center Cooling Rates when Quenched in Still Water
.5 .75 1 1.5 2
COOLING RATE, deg. f. per second at 1300 deg. f.
1000 900 800 665 600 470 400 370 315 270 240 210 185 155 135 115 94 77 64 54 44 37 30 25 20
ROCKWELL HARDNESS, "C" SCALE
70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
DISTANCE FROM WATER COOLED END OF L BAR — Sixteenths of In.

FIG. 13—STANDARD HARDENABILITY CHART FOR L BAR

Copies of the chart in 8½ by 11-in. size may be obtained from the SAE at nominal cost.

These smaller specimens, therefore, are useful only for comparing empirically the hardenability of successive heats of steel.

The test specimens are machined as shown in Fig. 14. The hole is slightly larger than the test piece. This provides an annular space to be filled with a low-melting alloy such as Wood's Metal which provides thermal contact between the test piece and its 1-in.-diameter cylindrical sheath. In use, the sheath is warmed above the melting point of the alloy, the required amount of Wood's Metal poured in, the test piece inserted, and the stud screwed in, forcing the test specimen firmly against the bottom of the hole. The assembly is then heated and quenched as prescribed for the standard hardenability test procedure. After the quench, the assembly is warmed in boiling water to melt the Wood's Metal and the test specimen removed and tested as prescribed for the standard specimen.

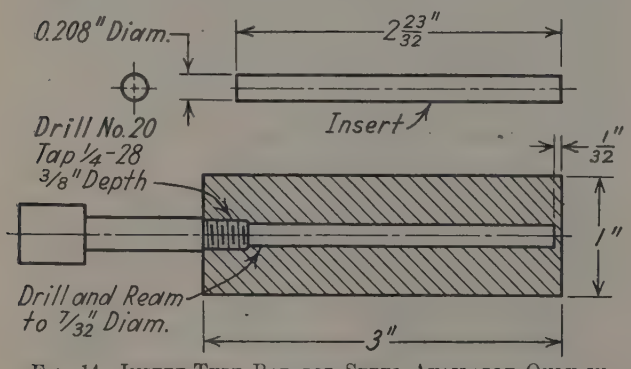


FIG. 14—INSERT-TYPE BAR FOR STEEL AVAILABLE ONLY IN SMALL SIZES

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Tension-Test Specimens

SAE General Information

Report of the Iron and Steel Division approved June 1911 and last revised January 1942. Information in this SAE General Information report on sub-size specimens conforms to Federal Specification QQ-M-151a except that the 0.437-in. pull diameter is omitted and the 0.160-in. pull diameter is added. Information on the other specimens conforms to ASTM E 8 – 42 T.

[*SAE steels are to be purchased on the basis of requirements as to chemical composition. (See the SAE Standards for Chemical Compositions of SAE Carbon Steels and Chemical Compositions of SAE Alloy Steels.) When the steel user desires physical tests, the test specimens shall be selected and prepared in accordance with this report. ASTM E 8 – 42 T gives more detailed information on specimens.*]

In recommending these specimens for use in tension tests, it is not intended to exclude entirely the use of other test specimens for special materials or for special forms of material. It is, however, recommended that, wherever it is feasible, the specimens be used.

The reduced sections of all specimens shall be machined in such a manner as to avoid leaving severe machining strains in the material. It is essential that the reduced section and the ends of the specimen be symmetrical with respect to the longitudinal axis of the specimen. In no case should the asymmetry of the tension test specimen exceed 0.01 in.

All specimens used for tension tests shall be finished so that the surfaces are smooth and free from nicks and tool marks. All ragged edges shall be smoothed.

Flat Test Specimens—The tension-test specimens shown in Fig. 1 are recommended for plate, shapes, and flat material having a thickness of $\frac{3}{16}$ in. or over.

For tension tests of wrought ferrous and nonferrous metal in the form of plate, sheet, flat wire, strip, band, and hoop ranging in thickness from 0.005 to, but not including, $\frac{1}{2}$ in., and widths

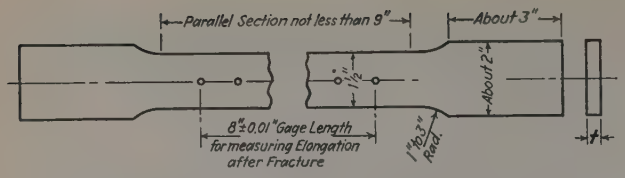


FIG. 1—TENSION-TEST SPECIMEN FOR PLATE MATERIAL

of $1\frac{1}{16}$ in. or greater, the test specimen described in the following paragraphs is recommended.

There should be gradual taper from ends of the reduced section to the middle. All machining dimensions are shown below and testing dimensions above the specimen. The ends shall be symmetrical within 0.01 in.

Fig. 2 shows the form of the finished specimen recommended for sheet metals.

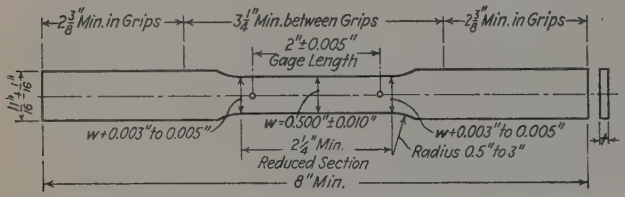


FIG. 2—TENSION-TEST SPECIMEN FOR SHEET METALS

Round Test Specimens—The tension-test specimen shown in Fig. 3 is recommended for general use in testing metals. The gage length for measuring elongation after fracture is 2 in. The radius shall be not less than ⅛ in.—a larger radius is preferable and for some materials necessary.

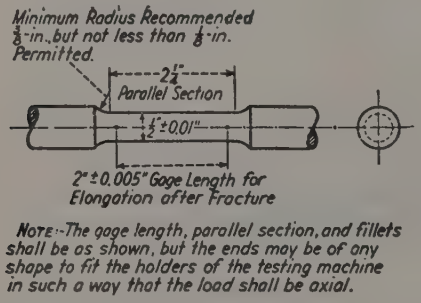

Minimum Radius Recommended ⅜ in., but not less than ⅛ in. Permitted.
2½" Parallel Section
½"±0.01"
2"±0.005" Gage Length for Elongation after Fracture
NOTE—The gage length, parallel section, and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial.

FIG. 3—ROUND TENSION-TEST SPECIMEN, 2-IN. GAGE LENGTH

The gage length, parallel section, and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load will be axial.

A slight taper of the parallel section not to exceed a maximum of 1% of the diameter within the gage length, similar to that shown in Fig. 2 for sheet materials, is desirable for all tension-test specimens.

The shape of the ends of the specimen shown in Fig. 3 is not specified. For specimens of brittle materials, it is desirable to have fillets of large radius at the ends of the gage length so that the diameter of the specimen changes gradually along its length from the minimum section at the gage length to the diameter at the ends. Fig. 4 shows two forms of end of specimen which have given satisfactory results in tests of brittle materials.

Tension-test specimens of wire and rod are frequently of the full size as fabricated. For the measurement of elongation of wire or rod not over ¼ in. in nominal diameter, the gage length of 10 in. is frequently used.

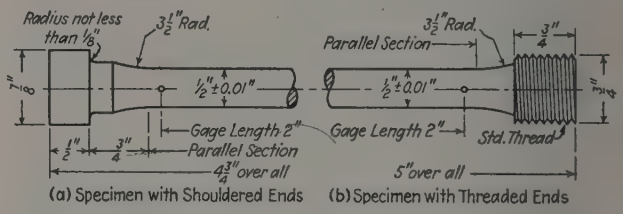


FIG. 4—ROUND TENSION-TEST SPECIMENS, THREADED AND SHOULDERED

Sub-Size Test Specimens[1]—When it is necessary to cut specimens from material (other than plate, shape, and flat material) which is of such size that the specimen shown in Fig. 3 cannot be used, it is recommended that a sub-size specimen, as described in Fig. 5 and Table 1, be used.

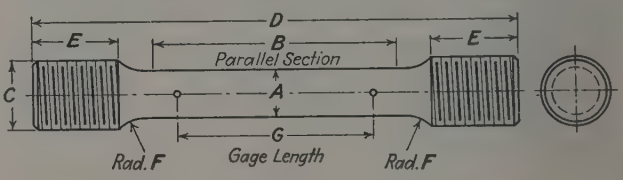


FIG. 5—SUB-SIZE TENSION-TEST SPECIMEN

TABLE 1—*Dimensions for Tension-Test Specimen Shown in Fig. 5*

A ±2%	*G*	*B*	*C* ±0.015	*D* APPROXIMATE	*E* APPROXIMATE	*F* RADIUS (MINIMUM)
0.357	1.4	1.750	0.500	3.500	0.625	0.25
0.252	1.0	1.250	0.375	3.000	0.625	0.18
0.160	0.634	0.750	0.312	2.000	0.437	0.15
0.113	0.4	0.625	0.250	1.625	0.375	0.09

When the use of an extensometer is required to determine the elastic properties, dimensions *G*, *B*, and *D* may be modified to provide therefor. In all cases the percentage of elongation shall be based on dimension *G* given in the above table.

[1] From Federal Specification QQ-M-151a, November 1939.

Hardness Tests and Hardness Number Conversions

SAE General Information

Report of Iron and Steel Division approved January 1946.

[*The accompanying conversion tables for steel hardness numbers are based on extensive tests on carbon and alloy steels, mostly in the heat-treated condition, but have been found to be reliable on practically all constructional alloy steels and tool steels in the as-forged, annealed, normalized, and quenched and tempered conditions, provided they are homogeneous. Such special cases as high-manganese steel, 18% chromium—8% nickel steel and other austenitic steels, and nickel-base alloys, as well as constructional alloy steels and tool steels in the cold-worked condition, may not conform to the relationships given with the same degree of accuracy as the steels for which the tables are intended.*

All numbers in these tables given in bold-face type were prepared jointly by the American Society for Testing Materials (E 48), the American Society for Metals, and the SAE from carefully checked data. The values given in regular-face type were taken from the Army-Navy Approximate Hardness-Tensile Strength Relationship of Carbon and Low-Alloy Steels (from AN-QQ-H-201) published in the 1943 SAE Handbook, with only minor adjustments.

The tables give the approximate relationship of DPH (Vickers), Brinell, Rockwell, and Scleroscope hardness values and corresponding approximate tensile strengths of steels. It is impossible to give exact relationships because of the inevitable influence of size, mass, composition, and method of heat-treatment. Where more precise conversions are required, they should be developed specially for each steel composition, heat-treatment, and part.]

Use of Conversion Tables—The conversions given in the accompanying Tables 1, 2, and 3 are recommended for use in converting the results of one form of hardness test to another only on flat surfaces and only when the specific test procedures and precautions outlined in the several hardness test methods are followed. Attention is called to the limitation in ASTM E 10 on the use of the standard steel ball to hardnesses under 500 Brinell. The Rockwell Superficial Hardness and the Diamond Pyramid Hardness tests require especially smooth surfaces for accurate results. In all tests, a specimen should be of sufficient thickness to avoid anvil effect—which thickness is roughly 10 times the depth of the indentation. It is important that conversions from Brinell hardness to shallow-impression-type tests, such as Rockwell Superficial and Diamond Pyramid Hardness tests, be made only on materials that are of uniform hardness to a depth at least 10 times that of the indentation. Such hardness conversions should not be made on surface-hardened, coated, or decarburized surfaces. Although the Rockwell Hardness and the Rockwell Superficial Hardness values in the tables are given to tenths of a point in order to maintain exact relationships between the various scales, it is customary to report these values to the nearest point. Experience has shown that even under carefully controlled conditions, some deviations from the conversion relationships will occur.

The numbers given in parentheses in the tables are values beyond the practical range of usefulness of the type of test under which they appear and have no strict application. They are included in the tables as a matter of information only.

Diamond Pyramid Hardness (Vickers, DPH), Table 1—Diamond Pyramid Hardness (DPH) is determined by forcing a square-base diamond pyramid having an apex angle of 136 deg into the test specimen under loads usually of 5 to 50 kg and measuring the diagonals of the recovered indentations. The Diamond Pyramid Hardness is defined as the load per unit area of surface contact in kilograms per square millimeter as calculated from the average diagonal as follows:

$$\text{DPH} = \frac{2L \sin \frac{a}{2}}{d^2}$$

where DPH = diamond pyramid hardness
d = length of average diagonal in millimeters
a = apex angle = 136 deg
L = load in kilograms

Brinell Hardness—Table 2 and 3—*Test Ball*—The diameter of the ball shall be 10.00 ± 0.01 mm (0.3937 ± 0.0004 in.) and shall be constant within ±0.0025 mm (0.0001 in.). The load applied shall be 3000 kg (6614 lb) for at least 10 sec on iron and steel.

Test Impression—The average diameter of the impression shall be obtained from two measurements at right angles to each other, made with an instrument having a reading error not over 0.01 mm (0.0004 in.).

Test Specimen—The surface of the specimen should be flat and reasonably free from scratches. The specimen shall be taken deep enough to represent the true composition of the material to be tested, and shall be maintained in a plane normal to the direction of the testing load.

Exceptions—This test should not be used on soft steels less than ½-in. thick or on areas small enough to permit deflection of the edges of the specimen owing to the flow from the ball depression.

For further information on standard methods of Brinell hardness testing, refer to ASTM E 10. For Brinell Hardness Numbers for Various Loads, see Table 3.

Rockwell Hardness—Table 4—*Principle of Test*—The Rockwell hardness tester is essentially a machine that measures hardness by determining the depth of penetration of a penetrator into the specimen under certain arbitrarily fixed conditions of test. The penetrator may be either a steel ball or a diamond sphero-conical penetrator. The hardness value as read from the dial is an arbitrary number which is related to the depth of indentation, and since the scales are reversed, the number is higher the harder the material. A minor load of 10 kg is first applied which causes an initial penetration which sets the penetrator on the material and holds it in position. The dial is set at zero on the black figure scale and the major load is applied. After the major load is applied and removed, according to standard procedure, the reading is taken while the minor load is still in position.

(*Text continued after Table 1.*)

TABLE 1—*Approximate Equivalent Hardness Numbers*[a] *for Diamond Pyramid Hardness Numbers (DPH, Vickers), for Steel*

DIAMOND PYRAMID HARDNESS NUMBER, VICKERS	BRINELL HARDNESS NUMBER, 10-MM BALL, 3000-KG LOAD			ROCKWELL HARDNESS NUMBER[b]				ROCKWELL SUPERFICIAL HARDNESS NUMBER, SUPERFICIAL BRALE PENETRATOR			SHORE SCLEROSCOPE HARDNESS NUMBER	TENSILE STRENGTH (APPROXIMATE) IN 1000 PSI	DIAMOND PYRAMID HARDNESS NUMBER, 50-KG LOAD
	Standard ball	Hultgren ball	Tungsten-carbide ball	A-scale, 60-kg load, brale penetrator	B-scale, 100-kg load, 1/16-in. diam ball	C-scale 150-kg load, brale penetrator	D-scale, 100-kg load, brale penetrator	15-N scale, 15-kg load	30-N scale, 30-kg load	45-N scale, 45-kg load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
940	—	—	—	85.6	—	68.0	76.9	93.2	84.4	75.4	97	—	940
920	—	—	—	85.3	—	67.5	76.5	93.0	84.0	74.8	96	—	920
900	—	—	—	85.0	—	67.0	76.1	92.9	83.6	74.2	95	—	900
880	—	—	767	84.7	—	66.4	75.7	92.7	83.1	73.6	93	—	880
860	—	—	757	84.4	—	65.9	75.3	92.5	82.7	73.1	92	—	860
840	—	—	745	84.1	—	65.3	74.8	92.3	82.2	72.2	91	—	840
820	—	—	733	83.8	—	64.7	74.3	92.1	81.7	71.8	90	—	820
800	—	—	722	83.4	—	64.0	73.8	91.8	81.1	71.0	88	—	800
780	—	—	710	83.0	—	63.3	73.3	91.5	80.4	70.2	87	—	780
760	—	—	698	82.6	—	62.5	72.6	91.2	79.7	69.4	86	—	760
740	—	—	684	82.2	—	61.8	72.1	91.0	79.1	68.6	84	—	740
720	—	—	670	81.8	—	61.0	71.5	90.7	78.4	67.7	83	—	720
700	—	615	656	81.3	—	60.1	70.8	90.3	77.6	66.7	81	—	700
690	—	610	647	81.1	—	59.7	70.5	90.1	77.2	66.2	—	—	690
680	—	603	638	80.8	—	59.2	70.1	89.8	76.8	65.7	80	329	680
670	—	597	630	80.6	—	58.8	69.8	89.7	76.4	65.3	—	324	670
660	—	590	620	80.3	—	58.3	69.4	89.5	75.9	64.7	79	319	660
650	—	585	611	80.0	—	57.8	69.0	89.2	75.5	64.1	—	314	650
640	—	578	601	79.8	—	57.3	68.7	89.0	75.1	63.5	77	309	640
630	—	571	591	79.5	—	56.8	68.3	88.8	74.6	63.0	—	304	630
620	—	564	582	79.2	—	56.3	67.9	88.5	74.2	62.4	75	299	620
610	—	557	573	78.9	—	55.7	67.5	88.2	73.6	61.7	—	294	610
600	—	550	564	78.6	—	55.2	67.0	88.0	73.2	61.2	74	289	600
590	—	542	554	78.4	—	54.7	66.7	87.8	72.7	60.5	—	284	590
580	—	535	545	78.0	—	54.1	66.2	87.5	72.1	59.9	72	279	580
570	—	527	535	77.8	—	53.6	65.8	87.2	71.7	59.3	—	274	570
560	—	519	525	77.4	—	53.0	65.4	86.9	71.2	58.6	71	269	560
550	505	512	517	77.0	—	52.3	64.8	86.6	70.5	57.8	—	264	550
540	496	503	507	76.7	—	51.7	64.4	86.3	70.0	57.0	69	260	540
530	488	495	497	76.4	—	51.1	63.9	86.0	69.5	56.2	—	254	530
520	480	487	488	76.1	—	50.5	63.5	85.7	69.0	55.6	67	250	520
510	473	479	479	75.7	—	49.8	62.9	85.4	68.3	54.7	—	244	510
500	465	471	471	75.3	—	49.1	62.2	85.0	67.7	53.9	66	240	500
490	456	460	460	74.9	—	48.4	61.6	84.7	67.1	53.1	—	234	490
480	448	452	452	74.5	—	47.7	61.3	84.3	66.4	52.2	64	230	480
470	441	442	442	74.1	—	46.9	60.7	83.9	65.7	51.3	—	224	470
460	433	433	433	73.6	—	46.1	60.1	83.6	64.9	50.4	62	220	460
450	425	425	425	73.3	—	45.3	59.4	83.2	64.3	49.4	—	214	450
440	415	415	415	72.8	—	44.5	58.8	82.8	63.5	48.4	59	210	440
430	405	405	405	72.3	—	43.6	58.2	82.3	62.7	47.4	—	204	430
420	397	397	397	71.8	—	42.7	57.5	81.8	61.9	46.4	57	200	420
410	388	388	388	71.4	—	41.8	56.8	81.4	61.1	45.3	—	195	410
400	379	379	379	70.8	—	40.8	56.0	81.0	60.2	44.1	55	190	400
390	369	369	369	70.3	—	39.8	55.2	80.3	59.3	42.9	—	185	390
380	360	360	360	69.8	(110.0)	38.8	54.4	79.8	58.4	41.7	52	180	380

(*Table continued on next page.*)

TABLE 1—*Approximate Equivalent Hardness Numbers*[a] *for Diamond Pyramid Hardness Numbers (DPH, Vickers), for Steel (Concluded)*

DIAMOND PYRAMID HARDNESS NUMBER, VICKERS	BRINELL HARDNESS NUMBER, 10-MM BALL, 3000-KG LOAD			ROCKWELL HARDNESS NUMBER[b]				ROCKWELL SUPERFICIAL HARDNESS NUMBER, SUPERFICIAL BRALE PENETRATOR			SHORE SCLEROSCOPE HARDNESS NUMBER	TENSILE STRENGTH (APPROXIMATE) IN 1000 PSI	DIAMOND PYRAMID HARDNESS NUMBER, 50-KG LOAD
	Standard ball	Hultgren ball	Tungsten-carbide ball	A-scale, 60-kg load, brale penetrator	B-scale, 100-kg load, 1/16-in. diam ball	C-scale, 150-kg load, brale penetrator	D-scale, 100-kg load, brale penetrator	15-N scale, 15-kg load	30-N scale, 30-kg load	45-N scale, 45-kg load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
370	**350**	**350**	**350**	**69.2**	—	**37.7**	**53.6**	**79.2**	**57.4**	**40.4**	—	175	**370**
360	**341**	**341**	**341**	**68.7**	(109.0)	**36.6**	**52.8**	**78.6**	**56.4**	**39.1**	50	170	**360**
350	**331**	**331**	**331**	**68.1**	—	**35.5**	**51.9**	**78.0**	**55.4**	**37.8**	—	166	**350**
340	**322**	**322**	**322**	**67.6**	(108.0)	**34.4**	**51.1**	**77.4**	**54.4**	**36.5**	47	161	**340**
330	**313**	**313**	**313**	**67.0**	—	**33.3**	**50.2**	**76.8**	**53.6**	**35.2**	—	156	**330**
320	**303**	**303**	**303**	**66.4**	(107.0)	**32.2**	**49.4**	**76.2**	**52.3**	**33.9**	45	151	**320**
310	**294**	**294**	**294**	**65.8**	—	**31.0**	**48.4**	**75.6**	**51.3**	**32.5**	—	146	**310**
300	**284**	**284**	**284**	**65.2**	(105.5)	**29.8**	**47.5**	**74.9**	**50.2**	**31.1**	42	141	**300**
295	**280**	**280**	**280**	**64.8**	—	**29.2**	**47.1**	**74.6**	**49.7**	**30.4**	—	139	**295**
290	**275**	**275**	**275**	**64.5**	(104.5)	**28.5**	**46.5**	**74.2**	**49.0**	**29.5**	41	136	**290**
285	**270**	**270**	**270**	**64.2**	—	**27.8**	**46.0**	**73.8**	**48.4**	**28.7**	—	134	**285**
280	**265**	**265**	**265**	**63.8**	(103.5)	**27.1**	**45.3**	**73.4**	**47.8**	**27.9**	40	131	**280**
275	**261**	**261**	**261**	**63.5**	—	**26.4**	**44.9**	**73.0**	**47.2**	**27.1**	—	129	**275**
270	**256**	**256**	**256**	**63.1**	(102.0)	**25.6**	**44.3**	**72.6**	**46.4**	**26.2**	38	126	**270**
265	**252**	**252**	**252**	**62.7**	—	**24.8**	**43.7**	**72.1**	**45.7**	**25.2**	—	124	**265**
260	**247**	**247**	**247**	**62.4**	(101.0)	**24.0**	**43.1**	**71.6**	**45.0**	**24.3**	37	121	**260**
255	**243**	**243**	**243**	**62.0**	—	**23.1**	**42.2**	**71.1**	**44.2**	**23.2**	—	119	**255**
250	**238**	**238**	**238**	**61.6**	99.5	**22.2**	**41.7**	**70.6**	**43.4**	**22.2**	36	116	**250**
245	**233**	**233**	**233**	**61.2**	—	**21.3**	**41.1**	**70.1**	**42.5**	**21.1**	—	114	**245**
240	**228**	**228**	**228**	**60.7**	98.1	**20.3**	**40.3**	**69.6**	**41.7**	**19.9**	34	111	**240**
230	219	219	219	—	96.7	(18.0)	—	—	—	—	33	106	230
220	209	209	209	—	95.0	(15.7)	—	—	—	—	32	101	220
210	200	200	200	—	93.4	(13.4)	—	—	—	—	30	97	210
200	190	190	190	—	91.5	(11.0)	—	—	—	—	29	92	200
190	181	181	181	—	89.5	(8.5)	—	—	—	—	28	88	190
180	171	171	171	—	87.1	(6.0)	—	—	—	—	26	84	180
170	162	162	162	—	85.0	(3.0)	—	—	—	—	25	79	170
160	152	152	152	—	81.7	(0.0)	—	—	—	—	24	75	160
150	143	143	143	—	78.7	—	—	—	—	—	22	71	150
140	133	133	133	—	75.0	—	—	—	—	—	21	66	140
130	124	124	124	—	71.2	—	—	—	—	—	20	62	130
120	114	114	114	—	66.7	—	—	—	—	—	—	57	120
110	105	105	105	—	62.3	—	—	—	—	—	—	—	110
100	95	95	95	—	56.2	—	—	—	—	—	—	—	100
95	90	90	90	—	52.0	—	—	—	—	—	—	—	95
90	86	86	86	—	48.0	—	—	—	—	—	—	—	90
85	81	81	81	—	41.0	—	—	—	—	—	—	—	85

[a] The values in this table shown in **bold-face type** correspond to the values shown in the corresponding joint SAE-ASM-ASTM Committee on Hardness Conversions as printed in ASTM E 48 – 43 T, Table 1.
[b] Values in ( ) are beyond normal range and are given for information only.

Preparation of Surfaces—Concordant results are dependent on surface roughness being much less than the size of the impression. Surfaces that are ridged perceptibly to the eye by rough grinding or machining offer unequal support to the penetrator. The degree of surface preparation then depends to some extent on the requirements of testing, whether they be production or research.

Thickness of Specimens—The minimum allowable thickness of any specimen varies according to the hardness, the load applied, and the kind of test point or penetrator used. The hardest steels give true hardness readings if over 0.027 in. in thickness.

Curved Surfaces—Data for hardness tests on a highly curved surface should be accompanied by a statement of the radius of curvature. In testing small rounds, the effect of curvature can be eliminated by making a small flat spot on the specimen.

(*Text continued after Table 2.*)

TABLE 2—*Approximate Equivalent Hardness Numbers*[a] *for Brinell Hardness Numbers*,[b] *for Steel*

BRINELL INDENTATION DIAMETER, MM	BRINELL HARDNESS NUMBER, 10-MM BALL, 3000-KG LOAD			DIAMOND PYRAMID HARDNESS NUMBER, VICKERS	ROCKWELL HARDNESS NUMBER[c]				ROCKWELL SUPERFICIAL HARDNESS NUMBER, SUPERFICIAL BRALE PENETRATOR			SHORE SCLEROSCOPE HARDNESS NUMBER	TENSILE STRENGTH (APPROXIMATE) IN 1000 PSI	BRINELL INDENTATION DIAMETER, MM
	Standard ball	Hultgren ball	Tungsten-carbide ball		A-scale, 60-kg load, brale penetrator	B-scale, 100-kg load, 1/16-in. diam ball	C-scale, 150-kg load, brale penetrator	D-scale, 100-kg load, brale penetrator	15-N scale, 15-kg load	30-N scale, 30-kg load	45-N scale, 45-kg load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15
—	—	—	—	940	85.6	—	68.0	76.9	93.2	84.4	75.4	97	—	—
—	—	—	—	920	85.3	—	67.5	76.5	93.0	84.0	74.8	96	—	—
—	—	—	—	900	85.0	—	67.0	76.1	92.9	83.6	74.2	95	—	—
—	—	—	767	880	84.7	—	66.4	75.7	92.7	83.1	73.6	93	—	—
—	—	—	757	860	84.4	—	65.9	75.3	92.5	82.7	73.1	92	—	—
2.25	—	—	745	840	84.1	—	65.3	74.8	92.3	82.2	72.2	91	—	2.25
—	—	—	733	820	83.8	—	64.7	74.3	92.1	81.7	71.8	90	—	—
—	—	—	722	800	83.4	—	64.0	73.8	91.8	81.1	71.0	88	—	—
2.30	—	—	712	—	—	—	—	—	—	—	—	—	—	2.30
—	—	—	710	780	83.0	—	63.3	73.3	91.5	80.4	70.2	87	—	—
—	—	—	698	760	82.6	—	62.5	72.6	91.2	79.7	69.4	86	—	—
—	—	—	684	740	82.2	—	61.8	72.1	91.0	79.1	68.6	—	—	—
2.35	—	—	682	737	82.2	—	61.7	72.0	91.0	79.0	68.5	84	—	2.35
—	—	—	670	720	81.8	—	61.0	71.5	90.7	78.4	67.7	83	—	—
—	—	—	656	700	81.3	—	60.1	70.8	90.3	77.6	66.7	—	—	—
2.40	—	—	653	697	81.2	—	60.0	70.7	90.2	77.5	66.5	81	—	2.40
—	—	—	647	690	81.1	—	59.7	70.5	90.1	77.2	66.2	—	—	—
—	—	—	638	680	80.8	—	59.2	70.1	89.8	76.8	65.7	80	329	—
—	—	—	630	670	80.6	—	58.8	69.8	89.7	76.4	65.3	—	324	—
2.45	—	—	627	667	80.5	—	58.7	69.7	89.6	76.3	65.1	79	323	2.45
2.50	—	601	—	677	80.7	—	59.1	70.0	89.8	76.8	65.7	—	328	2.50
	—	—	601	640	79.8	—	57.3	68.7	89.0	75.1	63.5	77	309	
2.55	—	578	—	640	79.8	—	57.3	68.7	89.0	75.1	63.5	—	309	2.55
	—	—	578	615	79.1	—	56.0	67.7	88.4	73.9	62.1	75	297	
2.60	—	555	—	607	78.8	—	55.6	67.4	88.1	73.5	61.6	—	293	2.60
	—	—	555	591	78.4	—	54.7	66.7	87.8	72.7	60.6	73	285	
2.65	—	534	—	579	78.0	—	54.0	66.1	87.5	72.0	59.8	—	279	2.65
	—	—	534	569	77.8	—	53.5	65.8	87.2	71.6	59.2	71	274	
2.70	—	514	—	553	77.1	—	52.5	65.0	86.7	70.7	58.0	—	266	2.70
	—	—	514	547	76.9	—	52.1	64.7	86.5	70.3	57.6	70	263	
2.75	495	—	—	539	76.7	—	51.6	64.3	86.3	69.9	56.9	—	259	2.75
	—	495	—	530	76.4	—	51.1	63.9	86.0	69.5	56.2	—	254	
	—	—	495	528	76.3	—	51.0	63.8	85.9	69.4	56.1	68	253	
2.80	477	—	—	516	75.9	—	50.3	63.2	85.6	68.7	55.2	—	247	2.80
	—	477	—	508	75.6	—	49.6	62.7	85.3	68.2	54.5	—	243	
	—	—	477	508	75.6	—	49.6	62.7	85.3	68.2	54.5	66	243	
2.85	461	—	—	495	75.1	—	48.8	61.9	84.9	67.4	53.5	—	237	2.85
	—	461	—	491	74.9	—	48.5	61.7	84.7	67.2	53.2	—	235	
	—	—	461	491	74.9	—	48.5	61.7	84.7	67.2	53.2	65	235	
2.90	444	—	—	474	74.3	—	47.2	61.0	84.1	66.0	51.7	—	226	2.90
	—	444	—	472	74.2	—	47.1	60.8	84.0	65.8	51.5	—	225	
	—	—	444	472	74.2	—	47.1	60.8	84.0	65.8	51.5	63	225	
2.95	429	429	429	455	73.4	—	45.7	59.7	83.4	64.6	49.9	61	217	2.95
3.00	415	415	415	440	72.8	—	44.5	58.8	82.8	63.5	48.4	59	210	3.00
3.05	401	401	401	425	72.0	—	43.1	57.8	82.0	62.3	46.9	58	202	3.05
3.10	388	388	388	410	71.4	—	41.8	56.8	81.4	61.1	45.3	56	195	3.10
3.15	375	375	375	396	70.6	—	40.4	55.7	80.6	59.9	43.6	54	188	3.15
3.20	363	363	363	383	70.0	—	39.1	54.6	80.0	58.7	42.0	52	182	3.20
3.25	352	352	352	372	69.3	(110.0)	37.9	53.8	79.3	57.6	40.5	51	176	3.25
3.30	341	341	341	360	68.7	(109.0)	36.6	52.8	78.6	56.4	39.1	50	170	3.30

(*Table continued on next page.*)

TABLE 2—*Approximate Equivalent Hardness Numbers for Brinell Hardness[a] Numbers,[b] for Steel (Concluded)*

BRINELL INDENTATION DIAMETER, MM	BRINELL HARDNESS NUMBER, 10-MM BALL, 3000-KG LOAD			DIAMOND PYRAMID HARDNESS NUMBER, VICKERS	ROCKWELL HARDNESS NUMBER[c]				ROCKWELL SUPERFICIAL HARDNESS NUMBER, SUPERFICIAL BRALE PENETRATOR			SHORE SCLEROSCOPE HARDNESS NUMBER	TENSILE STRENGTH (APPROXIMATE) IN 1000 PSI	BRINELL INDENTATION DIAMETER, MM
	Standard ball	Hultgren ball	Tungsten-carbide ball		A-scale, 60-kg load, brale penetrator	B-scale, 100-kg load, 1/16-in. diam ball	C-scale, 150-kg load, brale penetrator	D-scale, 100-kg load, brale penetrator	15-N scale, 15-kg load	30-N scale, 30-kg load	45-N scale, 45-kg load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15
3.35	**331**	**331**	**331**	**350**	**68.1**	(108.5)	**35.5**	**51.9**	**78.0**	**55.4**	**37.8**	48	166	**3.35**
3.40	**321**	**321**	**321**	**339**	**67.5**	(108.0)	**34.3**	**51.0**	**77.3**	**54.3**	**36.4**	47	160	**3.40**
3.45	**311**	**311**	**311**	**328**	**66.9**	(107.5)	**33.1**	**50.0**	**76.7**	**53.3**	**34.4**	46	155	**3.45**
3.50	**302**	**302**	**302**	**319**	**66.3**	(107.0)	**32.1**	**49.3**	**76.1**	**52.2**	**33.8**	45	150	**3.50**
3.55	**293**	**293**	**293**	**309**	**65.7**	(106.0)	**30.9**	**48.3**	**75.5**	**51.2**	**32.4**	43	145	**3.55**
3.60	**285**	**285**	**285**	**301**	**65.3**	(105.5)	**29.9**	**47.6**	**75.0**	**50.3**	**31.2**	—	141	**3.60**
3.65	**277**	**277**	**277**	**292**	**64.6**	(104.5)	**28.8**	**46.7**	**74.4**	**49.3**	**29.9**	41	137	**3.65**
3.70	**269**	**269**	**269**	**284**	**64.1**	(104.0)	**27.6**	**45.9**	**73.7**	**48.3**	**28.5**	40	133	**3.70**
3.75	**262**	**262**	**262**	**276**	**63.6**	(103.0)	**26.6**	**45.0**	**73.1**	**47.3**	**27.3**	39	129	**3.75**
3.80	**255**	**255**	**255**	**269**	**63.0**	(102.0)	**25.4**	**44.2**	**72.5**	**46.2**	**26.0**	38	126	**3.80**
3.85	**248**	**248**	**248**	**261**	**62.5**	(101.0)	**24.2**	**43.2**	**71.7**	**45.1**	**24.5**	37	122	**3.85**
3.90	**241**	**241**	**241**	**253**	**61.8**	100.0	**22.8**	**42.0**	**70.9**	**43.9**	**22.8**	36	118	**3.90**
3.95	**235**	**235**	**235**	**247**	**61.4**	99.0	**21.7**	**41.4**	**70.3**	**42.9**	**21.5**	35	115	**3.95**
4.00	**229**	**229**	**229**	**241**	**60.8**	98.2	**20.5**	**40.5**	**69.7**	**41.9**	**20.1**	34	111	**4.00**
4.05	223	223	223	234	—	97.3	(18.8)	—	—	—	—	—	—	4.05
4.10	217	217	217	228	—	96.4	(17.5)	—	—	—	—	33	105	4.10
4.15	212	212	212	222	—	95.5	(16.0)	—	—	—	—	—	102	4.15
4.20	207	207	207	218	—	94.6	(15.2)	—	—	—	—	32	100	4.20
4.25	201	201	201	212	—	93.8	(13.8)	—	—	—	—	31	98	4.25
4.30	197	197	197	207	—	92.8	(12.7)	—	—	—	—	30	95	4.30
4.35	192	192	192	202	—	91.9	(11.5)	—	—	—	—	29	93	4.35
4.40	187	187	187	196	—	90.7	(10.0)	—	—	—	—	—	90	4.40
4.45	183	183	183	192	—	90.0	(9.0)	—	—	—	—	28	89	4.45
4.50	179	179	179	188	—	89.0	(8.0)	—	—	—	—	27	87	4.50
4.55	174	174	174	182	—	87.8	(6.4)	—	—	—	—	—	85	4.55
4.60	170	170	170	178	—	86.8	(5.4)	—	—	—	—	26	83	4.60
4.65	167	167	167	175	—	86.0	(4.4)	—	—	—	—	—	81	4.65
4.70	163	163	163	171	—	85.0	(3.3)	—	—	—	—	25	79	4.70
4.80	156	156	156	163	—	82.9	(0.9)	—	—	—	—	—	76	4.80
4.90	149	149	149	156	—	80.8	—	—	—	—	—	23	73	4.90
5.00	143	143	143	150	—	78.7	—	—	—	—	—	22	71	5.00
5.10	137	137	137	143	—	76.4	—	—	—	—	—	21	67	5.10
5.20	131	131	131	137	—	74.0	—	—	—	—	—	—	65	5.20
5.30	126	126	126	132	—	72.0	—	—	—	—	—	20	63	5.30
5.40	121	121	121	127	—	69.8	—	—	—	—	—	19	60	5.40
5.50	116	116	116	122	—	67.6	—	—	—	—	—	18	58	5.50
5.60	111	111	111	117	—	65.7	—	—	—	—	—	15	56	5.60

[a] The values in this table shown in **bold-face type** correspond to the values shown in the corresponding joint SAE-ASM-ASTM Committee on Hardness Conversions as printed in ASTM E 48 – 43 T, Table 3.

[b] Brinell numbers are based on the diameter of impressed indentation. If the ball distorts (flattens) during test, Brinell numbers will vary in accordance with the degree of such distortion when related to hardnesses determined with a Vickers Diamond Pyramid, Rockwell Brale, or other penetrator which does not sensibly distort. At high hardnesses, therefore, the relationship between Brinell and Vickers or Rockwell scales is affected by the type of ball used. Steel balls (Standard or Hultgren) tend to flatten slightly more than carbide balls, resulting in larger indentation and lower Brinell number than shown by a carbide ball. Thus, on a specimen of 640 Vickers, a Hultgren ball will leave a 2.55 mm impression (578 BHN), and the carbide ball a 2.50 mm impression (601 BHN). Conversely, identical impression diameters for both types of ball will correspond to different Vickers or Rockwell values. Thus, if both impressions are 2.55 mm (578 BHN), material tested with a Hultgren ball has a Vickers Hardness 640, while material tested with a carbide ball has a Vickers Hardness 615.

[c] Values in ( ) are beyond normal range and are given for information only.

Rockwell Scales—The black figures are used only for the diamond penetrator (Brale) with various loads. Scale A applies when the major load is 60 kg, scale D when it is 100 kg, and scale C when the load is 150 kg. The red figures are used for readings obtained with ball penetrators regardless of size or magnitude of major load; scale B applies when the major load of 100 kg is applied to the 1/16-in. steel-ball penetrator. All data should be prefixed by a letter showing whether the values are on the A, B, C, or D scale.

Testing Cast Iron—Materials such as cast iron with graphite particles and some nonferrous materials whose crystalline aggregates are comparatively large must be tested with a penetrator of sufficient size to overcome local or grain hardness in order to secure mass hardness.

Superficial Hardness Tester—The Rockwell Superficial Hardness tester utilizes the same principle as the regular Rockwell tester, but employs a light minor load of 3 kg and a light major load of 15, 30, or 45 kg in conjunction with a more sensitive depth-measuring system. It is recommended for use on thin strip or sheet material, nitrided or lightly carburized pieces, finished pieces on which large test marks would be undesirable, areas near edges, extremely small parts or sections, and shapes that would collapse under the comparatively heavy test loads of the regular Rockwell tester. When the 120-deg diamond-cone penetrator is used, readings are designated by the letter N prefixed by the major load (that is, 15-N, 30-N, or 45-N). Similarly, the letter T prefixed by the major load is applied to readings taken with the 1/16-in. steel ball. Special penetrators for very soft

TABLE 3—*Brinell Hardness Numbers (10-Mm Ball Diameter)*

DIAM OF INDENTATION, MM	LOADS, KG						DIAM OF INDENTATION, MM	LOADS, KG						DIAM OF INDENTATION, MM	LOADS, KG					
	500	1000	1500	2000	2500	3000		500	1000	1500	2000	2500	3000		500	1000	1500	2000	2500	3000
2.00	158	316	473	632	788	945	3.50	50.3	101	151	201	252	302	5.00	23.8	47.6	71.5	95.2	119	143
2.05	150	300	450	600	750	899	3.55	48.9	97.8	147	196	244	293	5.05	23.3	46.6	70.0	93.2	117	140
2.10	143	286	428	572	714	856	3.60	47.5	95.0	143	190	238	285	5.10	22.8	45.6	68.5	91.2	114	137
2.15	136	272	409	544	681	817	3.65	46.1	92.2	139	184	231	277	5.15	22.3	44.6	67.0	89.2	112	134
2.20	130	260	390	520	650	780	3.70	44.9	89.8	135	180	225	269	5.20	21.8	43.6	65.5	87.2	109	131
2.25	124	248	373	496	621	745	3.75	43.6	87.2	131	174	218	262	5.25	21.4	42.8	64.0	85.6	107	128
2.30	119	238	356	476	593	712	3.80	42.4	84.8	128	170	212	255	5.30	20.9	41.8	63.0	83.6	105	126
2.35	114	228	341	456	568	682	3.85	41.3	82.6	124	165	207	248	5.35	20.5	41.0	61.5	82.0	103	123
2.40	109	218	327	436	545	653	3.90	40.2	80.4	121	161	201	241	5.40	20.1	40.2	60.5	80.4	101	121
2.45	104	208	314	416	522	627	3.95	39.1	78.2	118	156	196	235	5.45	19.7	39.4	59.0	78.8	98.5	118
2.50	100	200	301	400	500	601	4.00	38.1	76.2	115	152	191	229	5.50	19.3	38.6	58.0	77.2	96.5	116
2.55	96.3	193	289	385	482	578	4.05	37.1	74.2	112	148	186	223	5.55	18.9	37.8	57.0	75.6	95.0	114
2.60	92.6	185	278	370	462	555	4.10	36.2	72.4	109	145	181	217	5.60	18.6	37.2	55.5	74.4	92.5	111
2.65	89.0	178	267	356	445	534	4.15	35.3	70.6	106	141	177	212	5.65	18.2	36.4	54.5	72.8	90.8	109
2.70	85.7	171	257	343	429	514	4.20	34.4	68.8	104	138	172	207	5.70	17.8	35.6	53.5	71.2	89.2	107
2.75	82.6	165	248	330	413	495	4.25	33.6	67.2	101	134	167	201	5.75	17.5	35.0	52.5	70.0	87.5	105
2.80	79.6	159	239	318	398	477	4.30	32.8	65.6	98.5	131	164	197	5.80	17.2	34.4	51.5	68.8	85.8	103
2.85	76.8	154	231	307	384	461	4.35	32.0	64.0	96.0	128	160	192	5.85	16.8	33.6	50.5	67.2	84.2	101
2.90	74.1	148	222	296	371	444	4.40	31.2	62.4	93.5	125	156	187	5.90	16.5	33.0	49.6	66.0	82.5	99.2
2.95	71.5	143	215	286	358	429	4.45	30.5	61.0	91.5	122	153	183	5.95	16.2	32.4	48.7	64.8	81.2	97.3
3.00	69.1	138	208	276	346	415	4.50	29.8	59.6	89.5	119	149	179	6.00	15.9	31.8	47.8	63.6	79.5	95.5
3.05	66.8	134	201	267	334	401	4.55	29.1	58.2	87.0	116	145	174	6.05	15.6	31.2	46.9	62.4	78.0	93.7
3.10	64.6	129	194	258	324	388	4.60	28.4	56.8	85.0	114	142	170	6.10	15.3	30.6	46.0	61.2	76.7	92.0
3.15	62.5	125	188	250	313	375	4.65	27.8	55.6	83.5	111	139	167	6.15	15.1	30.2	45.2	60.4	75.3	90.3
3.20	60.5	121	182	242	303	363	4.70	27.1	54.2	81.5	108	136	163	6.20	14.8	29.6	44.4	59.2	73.8	88.7
3.25	58.6	117	176	234	293	352	4.75	26.5	53.0	79.5	106	133	159	6.25	14.5	29.0	43.6	58.0	72.6	87.1
3.30	56.8	114	171	227	284	341	4.80	25.9	51.8	78.0	104	130	156	6.30	14.2	28.4	42.8	56.8	71.3	85.5
3.35	55.1	110	166	220	276	331	4.85	25.4	50.8	76.0	102	127	152	6.35	14.0	28.0	42.0	56.0	70.0	84.0
3.40	53.4	107	161	214	267	321	4.90	24.8	49.6	74.5	99.2	124	149	6.40	13.7	27.4	41.3	54.8	68.8	82.5
3.45	51.8	104	156	207	259	311	4.95	24.3	48.6	73.0	97.2	122	146	6.45	13.5	27.0	40.5	54.0	67.5	81.0

metals or nonmetallic materials include ⅛-in., ¼-in., and ½-in. steel balls, designated by the letters X, Y, and Z, respectively. In using the Rockwell Superficial Hardness tester, the general methods prescribed for the regular Rockwell tester should be observed.

For further information on standard methods of Rockwell hardness testing of metallic materials, refer to ASTM E 18.

Shore Hardness—The Shore hardness number is the reading obtained on an arbitrary scale ranging from 0 to 120 by the rebound of a small diamond-pointed hammer dropped from a fixed height. Two types of instrument are in common use, one in which the rebound is read directly on a vertical scale and the other on which the reading is registered by the instrument on a recording dial. Readings are affected by variations in mass, form, surface, composition, and physical condition of different specimens being tested.

(*Continued on next page.*)

TABLE 4—*Approximate Equivalent Hardness Numbers*[a] *for Rockwell C Hardness Numbers, for Steel*

Rockwell C-scale hardness number[b]	Diamond pyramid hardness number, Vickers	Brinell hardness number 10-mm ball, 3000-kg load			Rockwell hardness number[b]			Rockwell, superficial hardness number, superficial brale penetrator			Shore scleroscope hardness number	Tensile strength (approximate) in 1000 psi	Rockwell C-scale hardness number[b]
		Standard ball	Hultgren ball	Tungsten-carbide ball	A-scale, 60-kg load, brale penetrator	B-sclae, 100-kg load, 1/16-in. diam ball	D-scale 100-kg load, brale penetrator	15-N scale, 15-kg load	30-N scale, 30-kg load	45-N scale, 45-kg load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
68	**940**	—	—	—	**85.6**	—	**76.9**	**93.2**	**84.4**	**75.4**	97	—	**68**
67	**900**	—	—	—	**85.0**	—	**76.1**	**92.9**	**83.6**	**74.2**	95	—	**67**
66	**865**	—	—	—	**84.5**	—	**75.4**	**92.5**	**82.8**	**73.3**	92	—	**66**
65	**832**	—	—	**739**	**83.9**	—	**74.5**	**92.2**	**81.9**	**72.0**	91	—	**65**
64	**800**	—	—	**722**	**83.4**	—	**73.8**	**91.8**	**81.1**	**71.0**	88	—	**64**
63	**772**	—	—	**705**	**82.8**	—	**73.0**	**91.4**	**80.1**	**69.9**	87	—	**63**
62	**746**	—	—	**688**	**82.3**	—	**72.2**	**91.1**	**79.3**	**68.8**	85	—	**62**
61	**720**	—	—	**670**	**81.8**	—	**71.5**	**90.7**	**78.4**	**67.7**	83	—	**61**
60	**697**	—	**613**	**654**	**81.2**	—	**70.7**	**90.2**	**77.5**	**66.6**	81	—	**60**
59	**674**	—	**599**	**634**	**80.7**	—	**69.9**	**89.8**	**76.6**	**65.5**	80	326	**59**
58	**653**	—	**587**	**615**	**80.1**	—	**69.2**	**89.3**	**75.7**	**64.3**	78	315	**58**
57	**633**	—	**575**	**595**	**79.6**	—	**68.5**	**88.9**	**74.8**	**63.2**	76	305	**57**
56	**613**	—	**561**	**577**	**79.0**	—	**67.7**	**88.3**	**73.9**	**62.0**	75	295	**56**
55	**595**	—	**546**	**560**	**78.5**	—	**66.9**	**87.9**	**73.0**	**60.9**	74	287	**55**
54	**577**	—	**534**	**543**	**78.0**	—	**66.1**	**87.4**	**72.0**	**59.8**	72	278	**54**
53	**560**	—	**519**	**525**	**77.4**	—	**65.4**	**86.9**	**71.2**	**58.6**	71	269	**53**
52	**544**	**500**	**508**	**512**	**76.8**	—	**64.6**	**86.4**	**70.2**	**57.4**	69	262	**52**
51	**528**	**487**	**494**	**496**	**76.3**	—	**63.8**	**85.9**	**69.4**	**56.1**	68	253	**51**
50	**513**	**475**	**481**	**481**	**75.9**	—	**63.1**	**85.5**	**68.5**	**55.0**	67	245	**50**
49	**498**	**464**	**469**	**469**	**75.2**	—	**62.1**	**85.0**	**67.6**	**53.8**	66	239	**49**
48	**484**	**451**	**455**	**455**	**74.7**	—	**61.4**	**84.5**	**66.7**	**52.5**	64	232	**48**
47	**471**	**442**	**443**	**443**	**74.1**	—	**60.8**	**83.9**	**65.8**	**51.4**	63	225	**47**
46	**458**	**432**	**432**	**432**	**73.6**	—	**60.0**	**83.5**	**64.8**	**50.3**	62	219	**46**
45	**446**	**421**	**421**	**421**	**73.1**	—	**59.2**	**83.0**	**64.0**	**49.0**	60	212	**45**
44	**434**	**409**	**409**	**409**	**72.5**	—	**58.5**	**82.5**	**63.1**	**47.8**	58	206	**44**
43	**423**	**400**	**400**	**400**	**72.0**	—	**57.7**	**82.0**	**62.2**	**46.7**	57	201	**43**
42	**412**	**390**	**390**	**390**	**71.5**	—	**56.9**	**81.5**	**61.3**	**45.5**	56	196	**42**
41	**402**	**381**	**381**	**381**	**70.9**	—	**56.2**	**80.9**	**60.4**	**44.3**	55	191	**41**
40	**392**	**371**	**371**	**371**	**70.4**	—	**55.4**	**80.4**	**59.5**	**43.1**	54	186	**40**
39	**382**	**362**	**362**	**362**	**69.9**	—	**54.6**	**79.9**	**58.6**	**41.9**	52	181	**39**
38	**372**	**353**	**353**	**353**	**69.4**	—	**53.8**	**79.4**	**57.7**	**40.8**	51	176	**38**
37	**363**	**344**	**344**	**344**	**68.9**	—	**53.1**	**78.8**	**56.8**	**39.6**	50	172	**37**
36	**354**	**336**	**336**	**336**	**68.4**	(109.0)	**52.3**	**78.3**	**55.9**	**38.4**	49	168	**36**
35	**345**	**327**	**327**	**327**	**67.9**	(108.5)	**51.5**	**77.7**	**55.0**	**37.2**	48	163	**35**
34	**336**	**319**	**319**	**319**	**67.4**	(108.0)	**50.8**	**77.2**	**54.2**	**36.1**	47	159	**34**
33	**327**	**311**	**311**	**311**	**66.8**	(107.5)	**50.0**	**76.6**	**53.3**	**34.9**	46	154	**33**
32	**318**	**301**	**301**	**301**	**66.3**	(107.0)	**49.2**	**76.1**	**52.1**	**33.7**	44	150	**32**
31	**310**	**294**	**294**	**294**	**65.8**	(106.0)	**48.4**	**75.6**	**51.3**	**32.5**	43	146	**31**
30	**302**	**286**	**286**	**286**	**65.3**	(105.5)	**47.7**	**75.0**	**50.4**	**31.3**	42	142	**30**
29	**294**	**279**	**279**	**279**	**64.7**	(104.5)	**47.0**	**74.5**	**49.5**	**30.1**	41	138	**29**
28	**286**	**271**	**271**	**271**	**64.3**	(104.0)	**46.1**	**73.9**	**48.6**	**28.9**	41	134	**28**
27	**279**	**264**	**264**	**264**	**63.8**	(103.0)	**45.2**	**73.3**	**47.7**	**27.8**	40	131	**27**
26	**272**	**258**	**258**	**258**	**63.3**	(102.5)	**44.6**	**72.8**	**46.8**	**26.7**	38	127	**26**
25	**266**	**253**	**253**	**253**	**62.8**	(101.5)	**43.8**	**72.2**	**45.9**	**25.5**	38	124	**25**
24	**260**	**247**	**247**	**247**	**62.4**	(101.0)	**43.1**	**71.6**	**45.0**	**24.3**	37	121	**24**
23	**254**	**243**	**243**	**243**	**62.0**	100.0	**42.1**	**71.0**	**44.0**	**23.1**	36	118	**23**
22	**248**	**237**	**237**	**237**	**61.5**	99.0	**41.6**	**70.5**	**43.2**	**22.0**	35	115	**22**
21	**243**	**231**	**231**	**231**	**61.0**	98.5	**40.9**	**69.9**	**42.3**	**20.7**	35	113	**21**
20	**238**	**226**	**226**	**226**	**60.5**	97.8	**40.1**	**69.4**	**41.5**	**19.6**	34	110	**20**
(18)	230	219	219	219	—	96.7	—	—	—	—	33	106	(18)
(16)	222	212	212	212	—	95.5	—	—	—	—	32	102	(16)
(14)	213	203	203	203	—	93.9	—	—	—	—	31	98	(14)
(12)	204	194	194	194	—	92.3	—	—	—	—	29	94	(12)
(10)	196	187	187	187	—	90.7	—	—	—	—	28	90	(10)
(8)	188	179	179	179	—	89.5	—	—	—	—	27	87	(8)
(6)	180	171	171	171	—	87.1	—	—	—	—	26	84	(6)
(4)	173	165	165	165	—	85.5	—	—	—	—	25	80	(4)
(2)	166	158	158	158	—	83.5	—	—	—	—	24	77	(2)
(0)	160	152	152	152	—	81.7	—	—	—	—	24	**75**	(0)

[a] The values in this table shown in **bold-face type** correspond to the values shown in the corresponding joint SAE-ASM-ASTM Committee on Hardness Conversions as printed in ASTM E 48 – 43 T, Table 2.

[b] Values in ( ) are beyond normal range and are given for information only.

Grain-Size Charts for Classification of Steels

SAE General Information

Report of Iron and Steel Division approved June 1934 and last revised January 1940.

[This SAE General Information report is based on the ASTM Standard Classification of Austenite Grain Size in Steels, ASTM Designation E 19 – 39 T. It is published here with permission of the ASTM, for the convenience of SAE Handbook users.]

Scope—This classification for austenite grain size comprises two sets of charts, one of them in idealized form intended to be used with any procedure for determining austenite grain size (Plate Series I), the other consisting of a series of photomicrographs showing the structures found in the carburized case in a carburizing (McQuaid-Ehn) test (Plate Series II). These two charts cover the same range of sizes, with identical size designations (Nos. 1 to 8), the use of the one or the other being a matter of individual preference. The manner of making the grain size test may of course be decisive as to which chart will be used.

Establishing Austenite Grain Size—As may be agreed upon between the manufacturer and the purchaser, austenite grain size[1, 2] shall in this classification be established either by

1. Carburizing at 1700 F (925 C) for 8 hr (the McQuaid-Ehn test), which is recommended for carburizing grades, and often employed for other grades as well, or

2. Heating at a temperature not over 50 F (28 C) above the normal heat-treating temperature and for not over 50% more than the normal heat-treating time, the normal values being those mutually agreed upon.

The rate of cooling depends on the method of treatment, as will be evident from the methods described in the next paragraphs.

Revealing the Grain Size—For revealing austenite grain size the following methods[3] are generally used:

1. Outlining the grains with cementite, as in carburizing (McQuaid-Ehn test) or as in high-carbon steels.

2. Outlining the grains with ferrite, as in the hypoeutectoid zone in carburizing, or in medium-carbon steels generally, or by an interrupted cooling or gradient quench on low-carbon steels.

3. Fine-pearlite outlining of martensite grains, as in eutectoid steels at a not quite fully hardened zone.

4. Appropriate etching of fully hardened martensite.

5. An oxidation method.

Measuring the Grain Size—The measurement of grain size shall be carried out by comparing the microscopic image at 100-diameters magnification with the standard grain-size chart in Plate Series I or II.[4] Absolute grain-sizes may be calculated from Table 1, which shows the sizes as they appear in the chart and also the actual grain sizes.

TABLE 1—*Grain-Size Relationships, Actual and as Observed at 100-Diameters Magnification*

GRAIN-SIZE NUMBER[a]	NUMBER OF GRAINS PER SQUARE INCH AS VIEWED AT 100 DIAMETERS		CALCULATED DIAMETER OF EQUIVALENT SPHERICAL GRAIN (NOT MAGNIFIED)		CALCULATED MEAN AVERAGE OF CROSS-SECTION OF GRAIN (NOT MAGNIFIED), SQ. IN.
	Mean	Range	In.	Mm	
1	1	¾ to 1½	0.0113	0.287	0.000 1
2	2	1½ to 3	0.00800	0.203	0.000 05
3	4	3 to 6	0.00567	0.144	0.000 025
4	8	6 to 12	0.00400	0.101	0.000 012 5
5	16	12 to 24	0.00283	0.0718	0.000 006 25
6	32	24 to 48	0.00200	0.0507	0.000 003 13
7	64	48 to 96	0.00142	0.0359	0.000 001 56
8	128	96 to 192	0.00100	0.0254	0.000 000 78

[a] With the present state of the art of steel making, the dividing line between coarse and fine is found at about No. 5 grain size.

Report—In reporting grain size, the test conditions should be stated, including the temperature and time used in establishing the austenite grain size, and the method of revealing the grain size.

Fracture Method—There are sets of fracture standards in which the grain size is judged from the appearance of the fracture. It has been found that the arbitrarily numbered fracture grain sizes agree very well with the arbitrarily numbered grain sizes presented in Plate Series I. This coincidence makes the fracture grain sizes interchangeable with the austenite grain sizes determined microscopically (except that "duplexing" or mixed grain size is not readily discernible in fractures). The sizes observed microscopically shall be considered the primary standard, since they can be determined with measuring instruments.

(Plate Series I begins on next page.)

[1] Numerous methods are in use for establishing austenite grain size, and a knowledge of grain-coarsening behavior is helpful in deciding which method to use. The size of austenite grains, in any particular steel, depends primarily on the temperature to which that steel is heated and the time it is held at the temperature. It should be remembered that the atmosphere in heating may affect the grain growth behavior at the outside of the piece.

[2] Austenite grain size is influenced by most previous treatments to which steel may have been subjected, as, for example, quenching, normalizing, hot working, and cold working. It is therefore advisable, when testing for austenite grain size, to consider the effects of prior or subsequent treatments on the precise piece (or typical piece) which is under consideration.

[3] Details of the five methods for ascertaining austenite grain size are briefly:

1. In the hypereutectoid zone of a McQuaid-Ehn test, or in hypereutectoid steels cooled from the austenitic condition, the austenite grain size is outlined by the cementite which precipitated in the grain boundaries. It is therefore possible to read the grain size by etching the micrographic specimen with a suitable etchant, such as nital or picral, or alkaline sodium picrate.

2. Ferrite precipitates in the austenite grain boundaries, thus indicating the austenite grain size in the hypoeutectoid zone in a McQuaid-Ehn test (see Plate Series II). Ferrite similarly outlines the former austenite grains in a medium-carbon steel (say 0.50% carbon), when it has been cooled slowly from the austenite range. In low-carbon steels (say 0.20% carbon), cooled slowly from the austenite range to room temperature, the amount of ferrite is so large that the former austenite grain size is masked; in this case, the steel may be cooled slowly to an intermediate temperature, to allow only a small amount of ferrite to precipitate, followed by quenching in water; an example would be a piece previously heated to 1675 F, transferred to a furnace at perhaps 1350 to 1450 F, held at this temperature for perhaps 3 to 5 min, and then quenched in water; the austenite grain size would be revealed by small ferrite grains outlining "low-carbon martensite" grains.

3. Two methods applicable particularly to eutectoid steels, which cannot be judged so readily by some other methods, are (a) to harden a bar of such size that it is fully hardened at the outside but not quite fully hardened in the interior, or (b) to employ a "gradient quench" in which the heated piece is for a portion of its length immersed in water and therefore fully hardened, the remainder of the piece projecting above the quenching bath, being therefore not hardened. With either method, there will be a small zone which is almost but not quite fully hardened. In this zone, the former austenite grains will consist of martensite grains surrounded by small amounts of fine pearlite ("nodular troostite"), thus revealing the grain size. These methods are also applicable to steels somewhat higher and lower than the eutectoid composition.

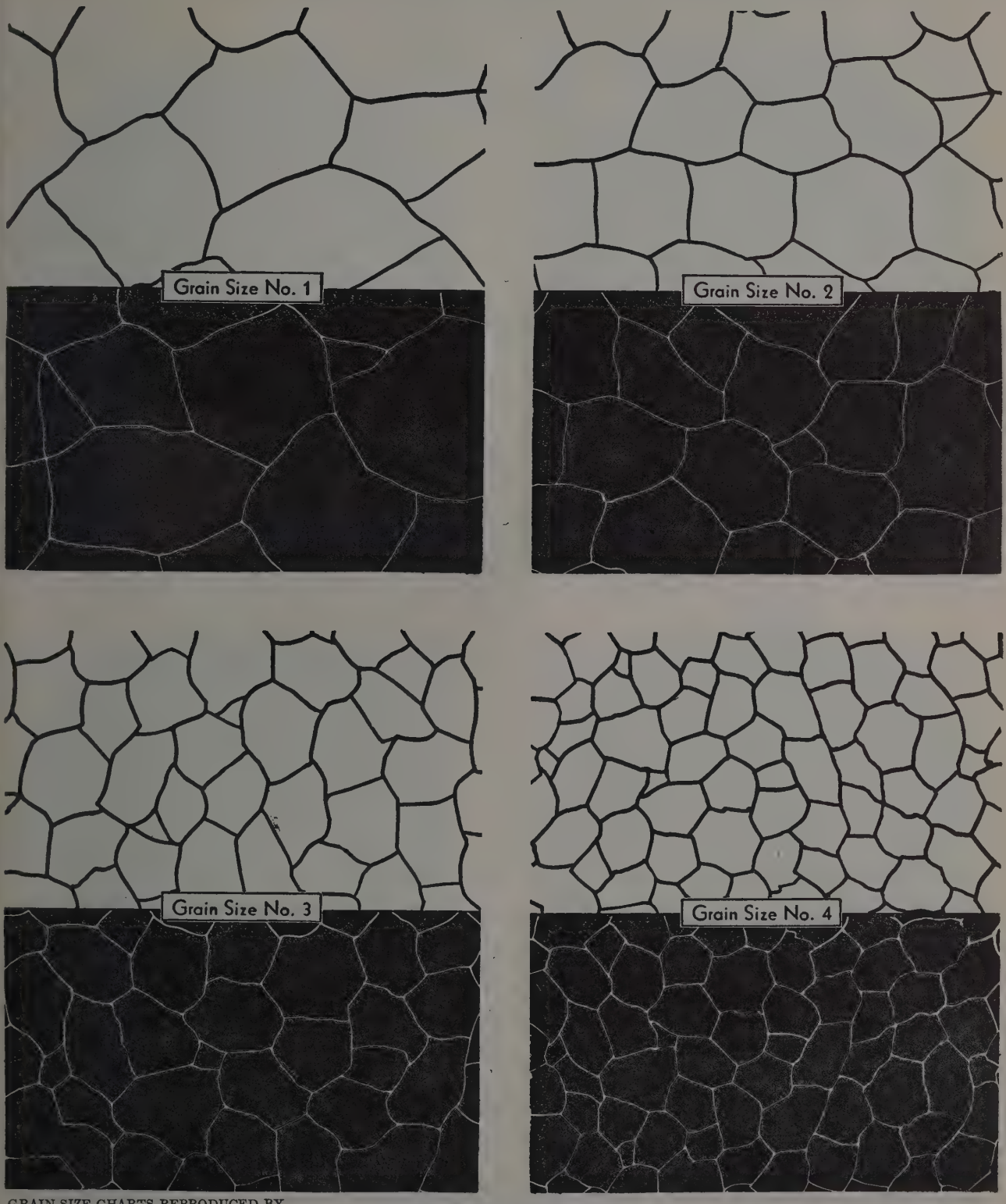
4. The former austenite grain size may be revealed in steels fully hardened to martensite by using an etching reagent which develops contrast between the martensite grains. A reagent which has been recommended is 1 g of picric acid, 5 ml of HCl (specific gravity 1.19), and 95 ml of ethyl alcohol. Tempering for 15 min at 450 F prior to etching distinctly improves the contrast.

5. The oxidation method depends on the fact that when steels are heated in an oxidizing atmosphere, oxidation takes place in part preferentially along the grain boundaries. A common procedure therefore is to polish the test specimen to a metallographic polish, heat it in air at the desired temperature for the desired length of time, and then repolish the specimen lightly so as merely to remove scale; whereupon the austenite grain boundaries are visible as outlined by oxide.

[4] Larger sizes Nos. 00 and 0 may be read by using a magnification of 50 diameters (instead of 100) and using grain sizes Nos. 1 and 2 on the chart, respectively. Smaller grain sizes Nos. 9 and 10 may be read by using a magnification of 200 diameters (instead of 100) and using grain sizes Nos. 7 and 8 on the chart, respectively.

Plate Series I—Grain Sizes Nos. 1, 2, 3, and 4

For Classification of SAE and Allied Structural Steels

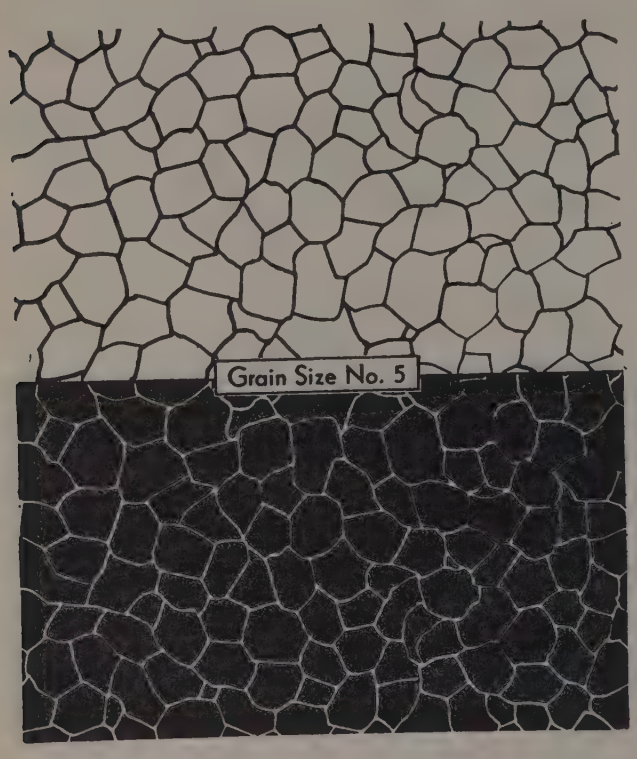


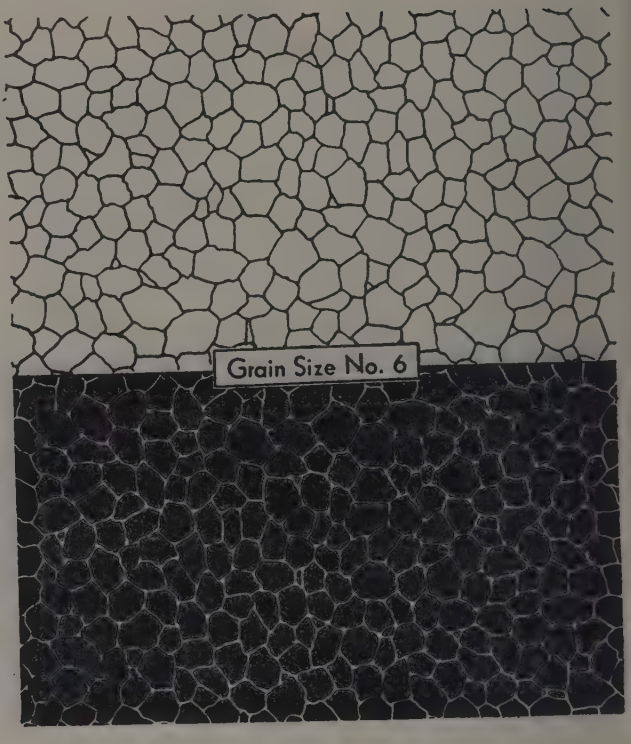
GRAIN-SIZE CHARTS REPRODUCED BY PERMISSION OF ASTM

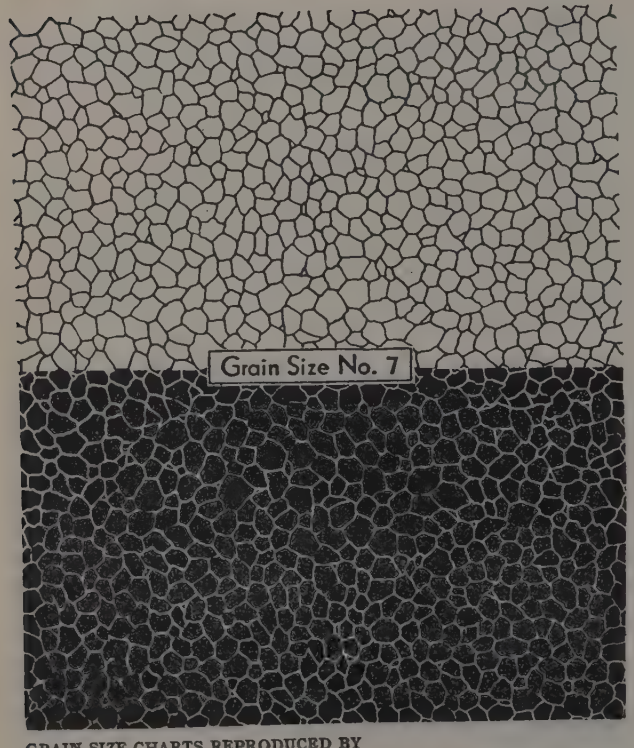
(Plate Series I continued on next page.)

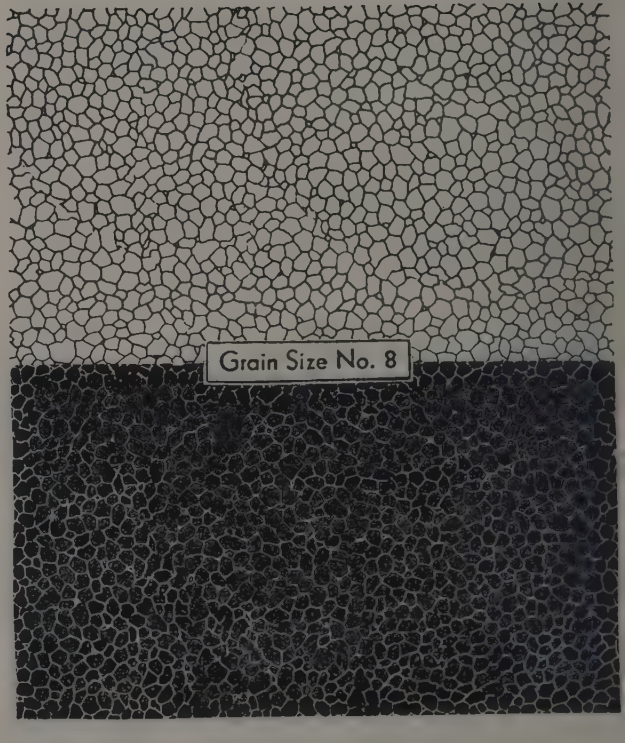
Plate Series I—Grain Sizes Nos. 5, 6, 7, and 8

For Classification of SAE and Allied Structural Steels







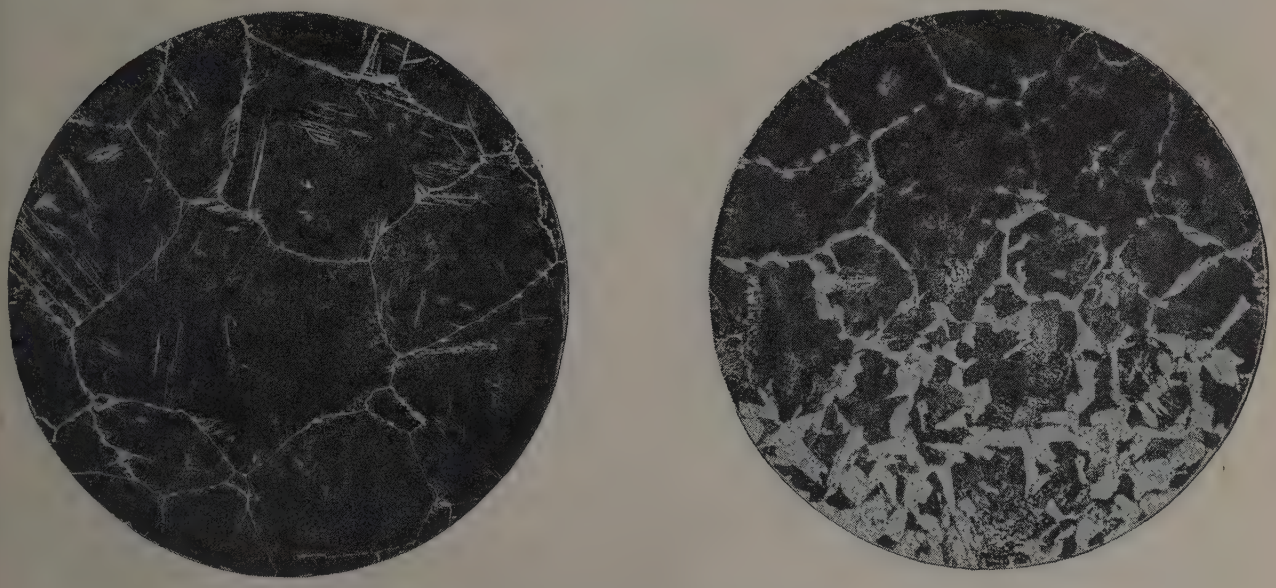


GRAIN-SIZE CHARTS REPRODUCED BY PERMISSION OF ASTM

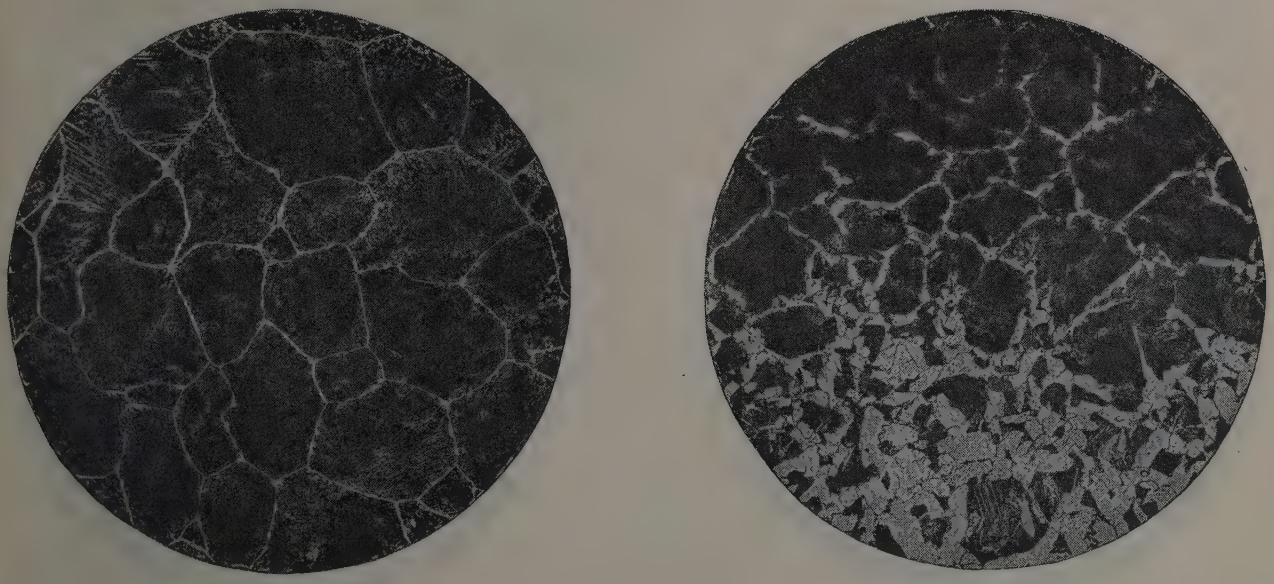
(Plate Series II begins on next page.)

Plate Series II—Grain Sizes Nos. 1 and 2

Samples were carburized at 1700 F (929 C) for 8 hr and magnified 100 times. Left-hand and right-hand photomicrographs for each grain size refer to hypereutectoid and hypoeutectoid zones, respectively, of the case



Grain Size No. 1—Up to 1½ Grains per Sq In.



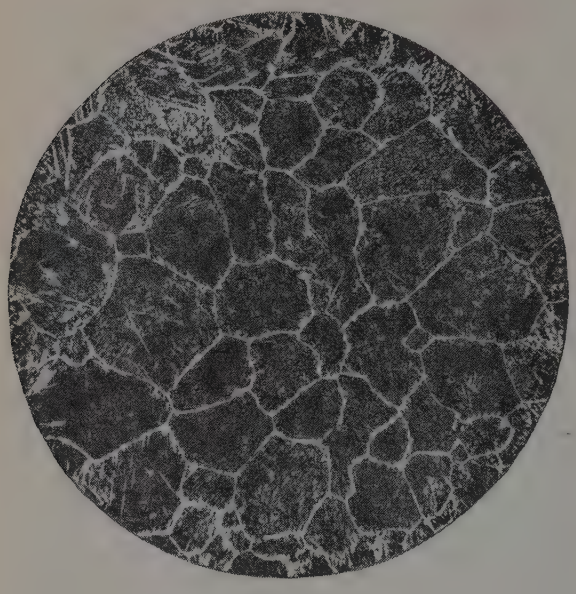
Grain Size No 2—1½ to 3 Grains per Sq In.

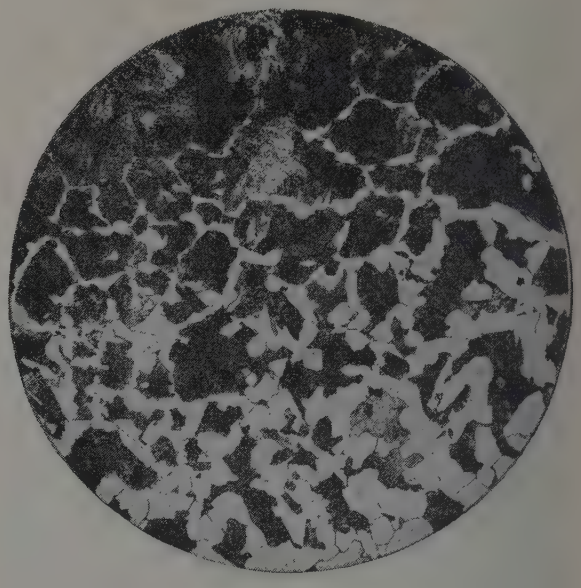
GRAIN-SIZE CHARTS REPRODUCED BY PERMISSION OF ASTM

(*Plate Series II continued on next page.*)

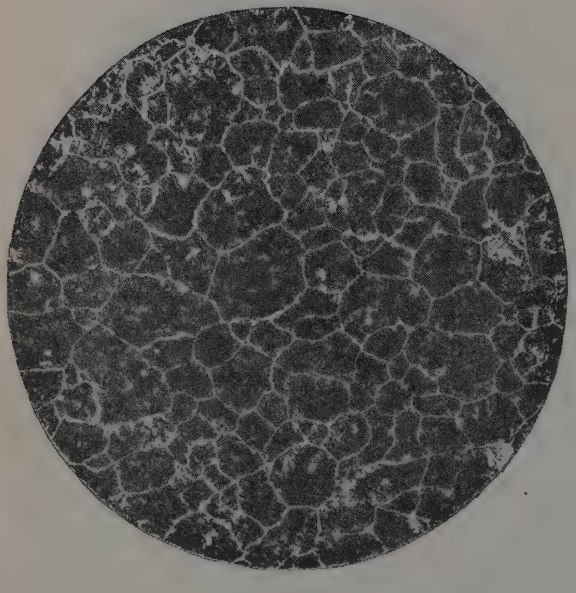
Plate Series II—Grain Sizes Nos. 3 and 4

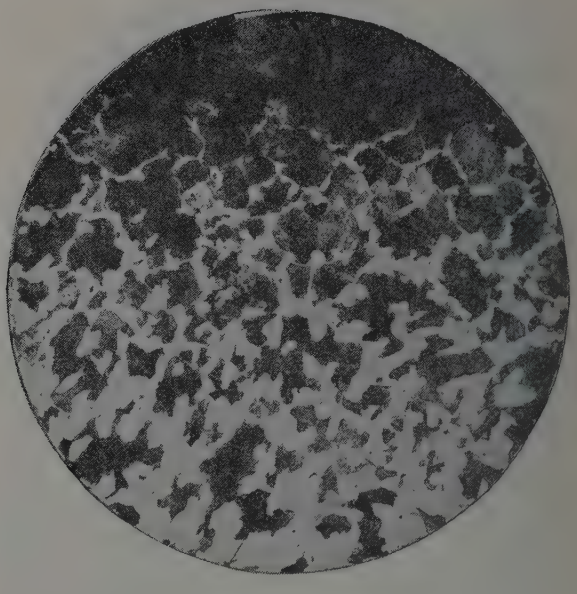
Samples were carburized at 1700 F (929 C) for 8 hr and magnified 100 times. Left-hand and right-hand photomicrographs for each grain size refer to hypereutectoid and hypoeutectoid zones, respectively, of the case





GRAIN SIZE NO. 3—3 TO 6 GRAINS PER SQ IN.





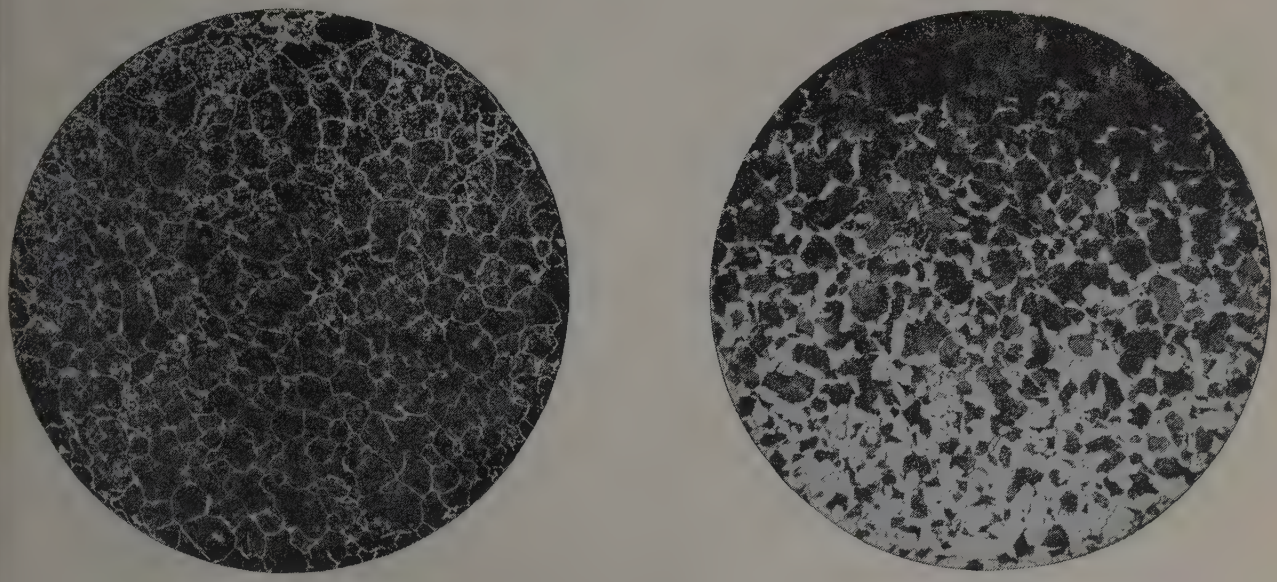
GRAIN SIZE NO. 4—6 TO 12 GRAINS PER SQ IN.

GRAIN-SIZE CHARTS REPRODUCED BY PERMISSION OF ASTM

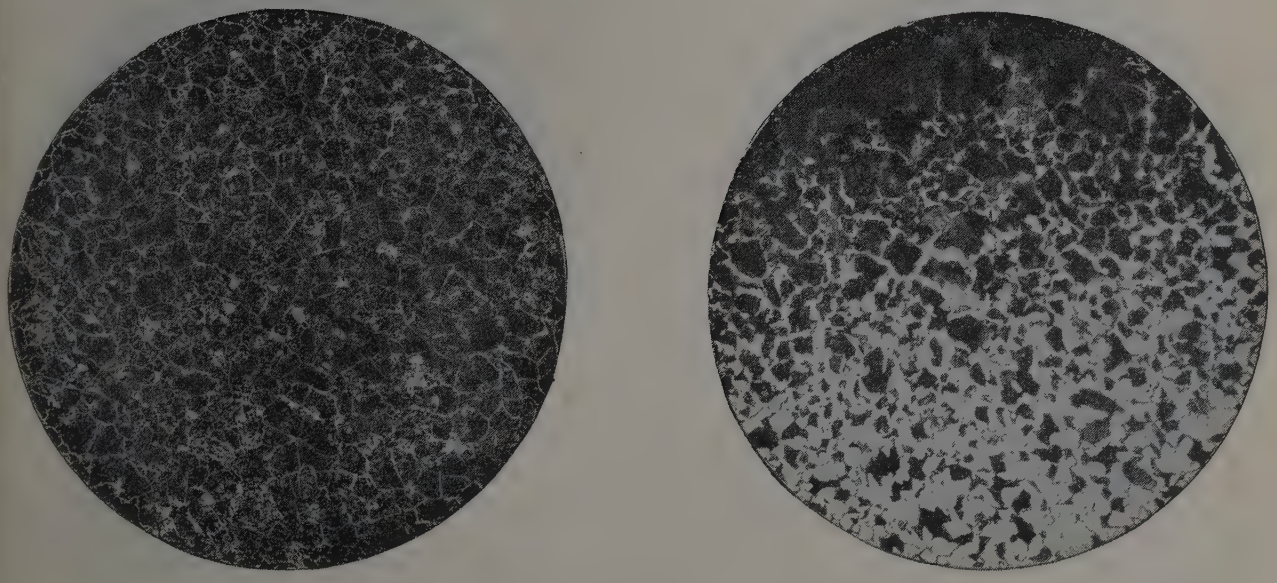
(*Plate Series II continued on next page.*)

Plate Series II—Grain Sizes Nos. 5 and 6

Samples were carburized at 1700 F (929 C) for 8 hr and magnified 100 times. Left-hand and right-hand photomicrographs for each grain size refer to hypereutectoid and hypoeutectoid zones, respectively, of the case



GRAIN SIZE NO. 5—12 TO 24 GRAINS PER SQ IN.



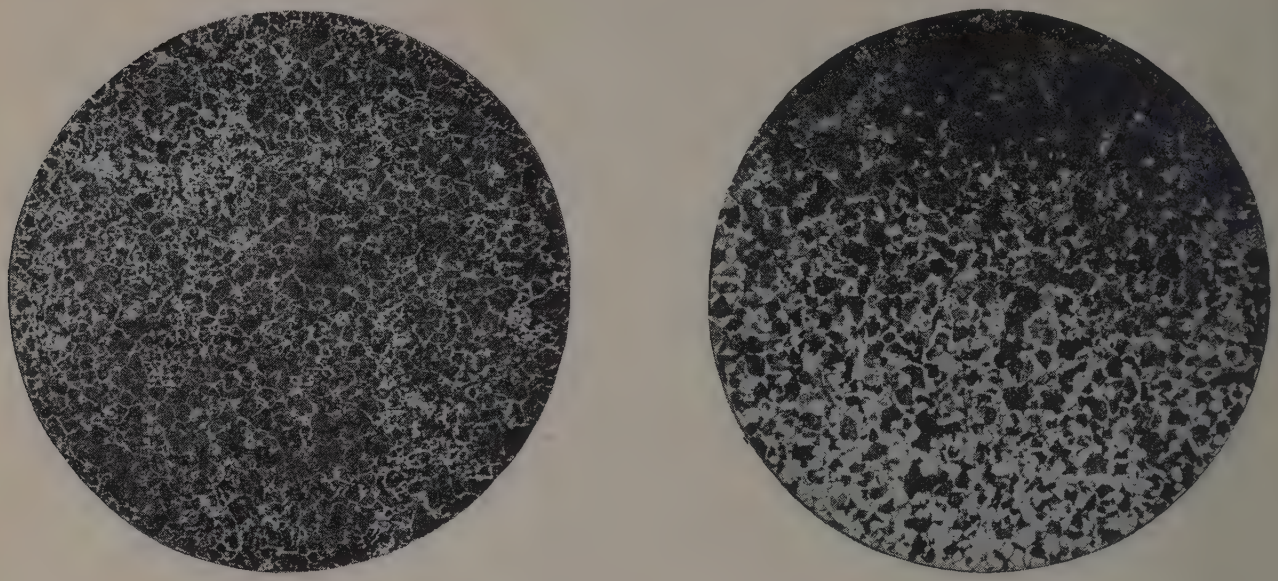
GRAIN SIZE NO. 6—24 TO 48 GRAINS PER SQ IN.

GRAIN-SIZE CHARTS REPRODUCED BY PERMISSION OF ASTM

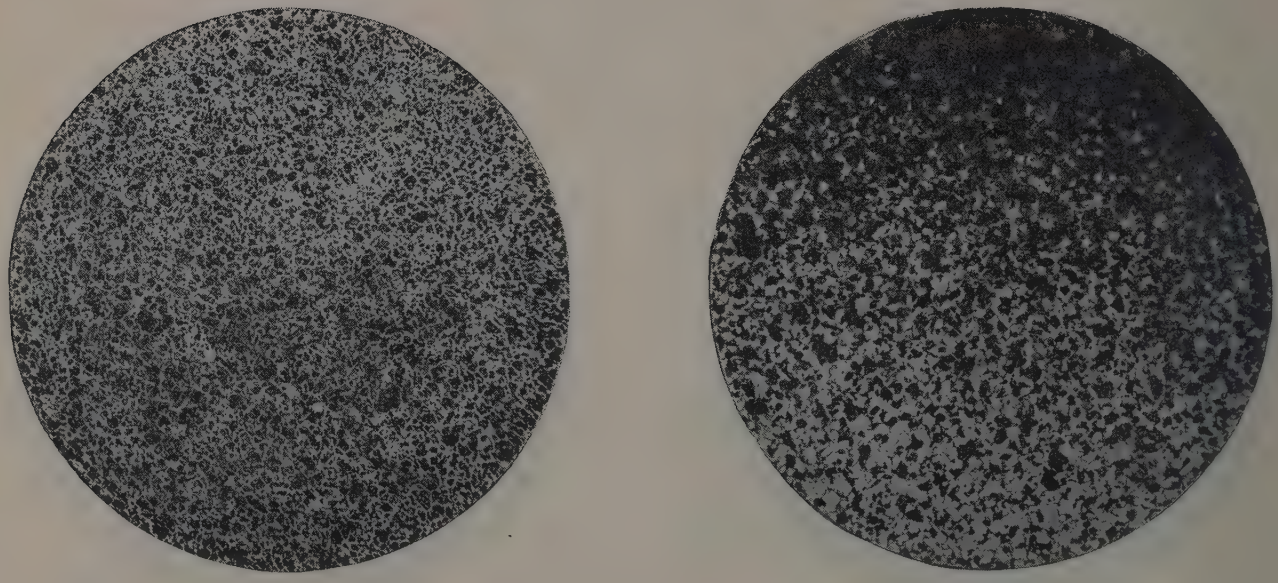
(*Plate Series II continued on next page.*)

Plate Series II—Grain Sizes Nos. 7 and 8

Samples were carburized at 1700 F (929 C) for 8 hr and magnified 100 times. Left-hand and right-hand photomicrographs for each grain size refer to hypereutectoid and hypoeutectoid zones, respectively, of the case



GRAIN SIZE NO. 7—48 TO 96 GRAINS PER SQ IN.



GRAIN SIZE NO. 8—96 AND MORE GRAINS PER SQ IN.

GRAIN-SIZE CHARTS REPRODUCED BY PERMISSION OF ASTM

Magnetic-Particle Testing of Steels

SAE Recommended Practice

Report of Iron and Steel Division approved January 1941 and last revised January 1942.

[The accompanying rating system is a simple code whereby the number, length, and distribution of the magnetic-particle lines may be expressed on the basis of a square foot of surface examined regardless of the size of the sample. In general, it is suggested that for convenience in handling and counting, the sample should be not less than 5 in. long.

The rating system is not intended as a direct index of quality, but rather as a shorthand description of the indications observed on the surface of the sample.

At its meeting on September 18, 1944, the Executive Committee of the Iron and Steel Division authorized changing magnaflux to "magnetic particles" throughout this specification.]

Sampling—Experience has shown that sampling of steel for magnetic-particle rating is primarily a matter of agreement between producer and consumer. Therefore the following "sampling" recommendations are to be used only as a guide in establishing individual sampling and testing procedures.

1. Samples for magnetic-particle examination and rating of steel should be 6 to 12 in. long, depending upon the size of the material to be tested.[1]

2. Magnetic-particle samples should be made from representative specimens from the bottom of the first ingot and the top of the last ingot of each heat of steel. If either of these tests yields questionable results, the heat is subject to further inspection.

3. Magnetic-particle samples may be rolled or forged,[2] and should be heat-treated, rough machined, and suitably finished.

4. The magnetic-particle tests should be performed according to the method given in this SAE Recommended Practice or by other suitable methods.

5. Macro-etch cross-sections should be made from mill sections representative of each heat of steel.

6. Complete chemical analyses should be made on two random samples from each heat. This may be done on the magnetic particle samples or on any of the marco-etch sections.

Code Factors

1. The total number of lines per square foot.
2. The aggregate length of all the lines per square foot.
3. The length (inches) of the longest single line.
4. A letter, *A*, *B*, *C*, or *D*, indicating the uniformity of distribution.

The length of the longest line is given to the nearest 0.1 in. and the aggregate length to the nearest inch.

The letter *A* indicates uniform distribution, *B* a slight tendency toward grouping, *C* an arrangement of discernible groups, and *D* well-defined or concentrated groups or clusters.

To distinguish indications of exceptionally heavy nature, the letter *H* may be added to the figure giving the length of the longest line, Item 3. In case the average lines, rather than only the longest line, might be heavy, the letter *H* might be added to the aggregate length of all the lines, Item 2.

Indications of "pepper-and-salt" nature, less than 0.1 in. in length, are not to be counted as lines but are regarded as background, and unless in large numbers, will be disregarded. When in large numbers, their presence will be mentioned after the four rating items, by appropriate descriptive words.

Where indications of less than 0.1-in. length occur in "ranks," or strung out end-to-end, they will be counted as lines whenever the spaces or interruptions between them are less than 0.1 in. across. When the spaces or interruptions are more than 0.1 in. across, these short indications will be disregarded.

Example—The accompanying facsimile, Fig. 1, reduced from a 6 x 6-in. drawing of the magnetic-particle lines as they appear on a sample of steel bar, serves to explain the use of the suggested system of rating.

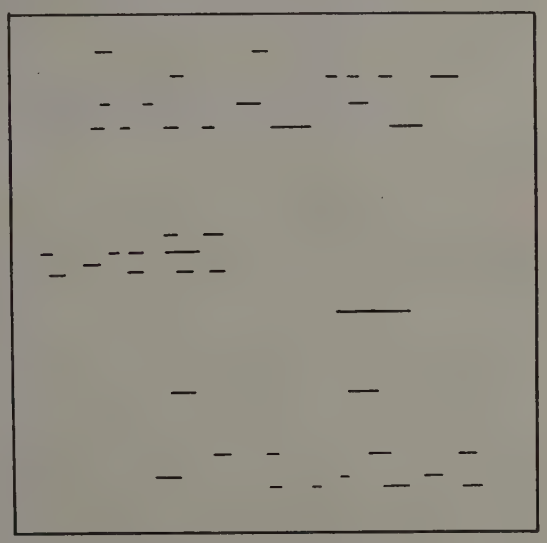


FIG. 1—FACSIMILE OF MAGNETIC-PARTICLE LINES ON A STEEL BAR (Reduced from 6 x 6 in.)

The number of lines found on the sample is 42. This, multiplied by the ratio 1/0.25 = 168 for the total number of lines per square foot.

The total length of all the lines on the surface of the sample is 5 in. The sample had an area of 0.25 sq ft. The aggregate length of all the lines per square foot then would be 5 x 1/0.25 = 20.

The longest line appearing on the surface is approximately 0.7 in. in length, so the third number of the code group would be 0.7. If this line were heavy, the third number of the code group would have *H* affixed, thus: 0.7*H*.

By examination, the lines are found to be arranged in distinct

[1] Longer samples are used for the smaller sizes of material, and shorter samples are used for the larger sizes.

[2] If samples are forged, the forging should be by elongation and reducing the cross-section evenly and gradually, similarly to rolling, and not by "steps" or "bites." When agreed, samples may be made from bloom size stock, reduced to bar, billet, or finished size.

groups. The symbol *C* should, therefore, be used to describe the distribution of the lines on the sample.

Thus, the code number to express the appearance of the lines observed on this sample would be:

168-20-0.7*H*-*C*

Discussion—By this code, a brief, concise expression carries a considerable amount of information:

1. There were magnetic-particle indications occurring at the rate of 168 per sq ft of area.

2. The aggregate length of all the lines per square foot of area was 20 in.

3. The longest line was approximately 0.7 in. long and was a heavy line.

4. On the specimen, these were arranged in distinct groups.

Analysis of count and length shows further that the average length is 20/168 = 0.119 in. At least one line (0.7) is much longer than the average. If its length is deducted from the total, then the average length of the remaining 167 lines is 0.115 in. In either case, the average length may be said to be ⅛ in. on the particular sample represented here for example.

General Recommendations

1. It is recommended that the standard of acceptance or rejection of material be a matter of agreement between the producer and the user.

2. It is recommended that the method of magnetic-particle testing employed be representative of the wet continuous method.

3. It is further recommended that:

(*a*) Not less than 700 and not more than 1200 amp of direct current per inch of sample diameter be used, and that in no case should the amount of current used be enough to indicate flow lines if such are present.

(*b*) Not more than three "shots" be used.

(*c*) The relay timing should be ⅛ to ½ sec per "shot."

(*d*) The whole operation of testing, including the three "shots" and the spraying or pouring of the vehicle bearing the magnetic substance over the test piece, consume from 3 to 5 sec.

(*e*) When using the flowing-on method of applying the vehicle containing the magnetic substance, care should be taken not to continue the application after cessation of current flow. Care should also be taken not to wash off indications by directing too strong a flow of vehicle against the part being tested; nor to permit building up of an indication by allowing the magnetic substance to concentrate on horizontal surfaces due to too light flow and puddling of the vehicle. When using the regular hand nozzle, the pump and nozzle should be so adjusted as to cause the vehicle to be ejected to a height of from 1½ to 2 in. above the nozzle when it is held vertically. When flowing the vehicle over the work, the nozzle should be so directed as to provide a smooth flow over the test surfaces, while not permitting the stream to impinge directly against test surfaces.

(*f*) Uniform suspension of the magnetic substance in the vehicle be maintained.

(*g*) The concentration of the magnetic substance[3] or paste[4] in the vehicle[5] be maintained between the limits of 1 to 1¾% maximum. This is equivalent to 1 oz, approximately, of magnetic paste per gallon of vehicle, and may be conveniently measured with a 100-cc centrifuge tube filled from the nozzle of the hose of the magnetic-particle machine, demagnetized, and read directly, after settling 30 min.

4. It is recommended that the sample or specimen to be tested and examined be as representative as is practicable of the finished part, and it is considered particularly important that:

(*a*) The diameter be that, or approximately that, of the finished part, unless otherwise agreed between producer and user.

(*b*) The sample or specimen be heat-treated or otherwise prepared to simulate the properties and condition of the finished part.

(*c*) The specimen or sample have a turned, ground, or otherwise prepared finish at least equivalent to 20 microin. (rms).

(*d*) In all cases the sample or specimen should have a machining operation sufficient to remove all surface defects resulting from forging, rolling, heat-treating, and so forth.

Method of Recording Magnetic-Particle Indications by the Imbibition Paper Process—The magnetic-particle coupon has a recording length of 6 in. An extension is optional for a tong hold for convenience in handling.

The coupon is machined to approximately the required size and is then ground and polished, ready for magnetic-particle testing.

The coupon is stamped (Fig. 2) at any point along the circumference to indicate the zero position of the test so that further comparisons may be made with accuracy. Then the coupon is magnetic-particle tested by the wet method, rinsed in carbon tetrachloride, and allowed to dry thoroughly.

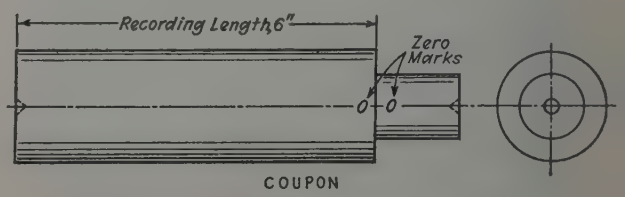


FIG. 2 MAGNETIC-PARTICLE TEST SPECIMEN

After magnetic-particle testing, the specimen is washed and dried, and is then ready for inspection. To plot the indications directly by rolling the specimen on the paper, the material called "imbibition paper" is used. For making the permanent print, the paper is cut to conform to the surface of the specimen to be plotted. It is then soaked in tepid water to soften, the excess water rolled out, and the paper laid on a flat metal surface, gelatin side up.

The final operation is made by rolling the test specimen over the gelatin surface (Fig. 3), being careful to place the zero marking as near the beginning of the roll as possible, and to place the

[3] Iron oxide powder or powdered iron oxide.

[4] *No. 7 Black Paste*—This material shall consist of a fine magnetic oxide dispersed in an oily medium which, when mixed with a light oil to make up an inspection bath, shall maintain a satisfactory suspension and must not tend to agglomerate rapidly in suspension. A dispersing agent should be incorporated to prevent agglomeration and to disperse the particles in suspension. The magnetic oxide employed shall consist of at least 85% magnetic oxide of iron. The material in paste form shall contain at least 75% of solid oxide of iron. It shall not cake badly in the container in storage.

No. 9 Red Paste—This is the same as No. 7, Black except it is the gamma form of ferric oxide, Fe_2O_3 and is bright red in color.

[5] Recommended suspensoid:

Baume, 46 API deg
Viscosity, 41 SU sec
Flash Point, (Tagliabue Open Cup), 165 F
Distillation, Initial Point, 390 F
Distillation, End Point, 490 F
Color (Saybolt Chromometer), 25

This distillate is somewhat heavier than kerosene, but in the absence of an oil of this character, kerosene is a fairly satisfactory substitute. A small amount of heavier oil may be allowed to prevent sore hands.

There is a trend in the aircraft industry to use a lighter suspensoid such as Stoddard solvent.

specimen as near the right-hand edge as possible, always rolling at right angles to the width of the paper. This will leave margins for notes.

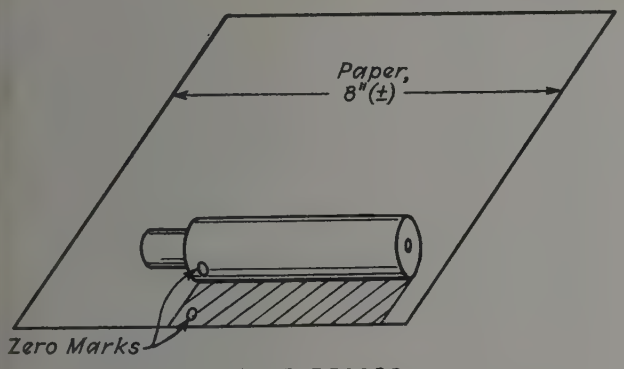


FIG. 3—METHOD OF ROLLING SPECIMEN ON PAPER
Note the zero marking on the circumference. In further operations, this index must be preserved for comparative purposes. Paper must be absolutely free of surface moisture. Note position of zero relative to paper when rolling

The specimen is rolled 360 deg so that the entire circumference comes in contact with the paper, and any magnetic-particle indications are transferred directly. The paper is dried and then fixed with Bristol's smoke-chart solution. This leaves a permanent picture of all magnetic-particle indications and represents the actual surface condition of the material.

The charts are then indexed and, after inspection, filed for future reference.

Method of Recording Magnetic-Particle Indications by the Transfer Process—This method affords a semi-permanent record, due to the tendency of the cellulose tape to discolor in time. Specifications for the materials for the transfer process follow.

Powder Suspension—Black magnetic-particle paste No. 7 offers a convenient source of magnetic powder and is prepared as follows:

Break up by stirring or by allowing to stand for some time approximately 1 oz of the commercial paste in about 200 cc of oil-free carbon tetrachloride, CCl_4. Technical-grade CCl_4 is satisfactory. When the paste has thoroughly disintegrated, stir well, allow to settle momentarily, and decant the liquid which still contains the greater portion of the powder. Reject the residue which contains the coarser particles and grease lumps. Allow the accepted suspension to settle out completely, and then decant or separate the clear CCl_4. Reject this, as it contains the grease in which the magnetic powder is ground. Wash the grease-free powder residue in about 100 cc of fresh CCl_4, allow to settle, and again decant. The residue remaining from these operations is then suspended in fresh CCl_4 to form the suspension. This amount of treated powder should give a satisfactory suspension in about 500 cc of CCl_4, but it is impossible to specify exactly the required solid relation. Depending on the type of defect or flaw to be treated, more or less concentrated suspensions are necessary, and it is impossible to maintain a fixed concentration of powder in such a volatile liquid. One ounce of magnetic-particle paste so treated in 500 cc of CCl_4, gives a suspension suitable for most routine work, but it may be necessary at times to dilute the suspension, or allow it to concentrate by standing. In general, it is best to use a weak suspension to prevent the powder from piling up on the defects.

Cleaning Suspensions—For ordinary work, oil-free CCl_4 alone is suitable for a working suspension. The thin layer of magnetic powder which remains on the surface of the specimen, even after washing, is sufficient to prevent the adhesive from sticking to the metal. But on highly polished surfaces, and particularly when working at room temperatures above 80 F, additional dusting of the metal is required. In these rare cases, use a cleaning suspension of oil-free CCl_4 in which is suspended chalk or zinc stearate. A very small amount of solid, about 1 gr per 1000 cc will suffice to prevent the adhesive from clinging to the metal, and still not blur the pattern.

Transfer Medium—Scotch cellulose tape or cellulose mending tape,[6] is used as a transfer medium in this process. The material may be purchased in various lengths and widths, in convenient rolls. The width required depends on the size of the area to be recorded. The material should show no bubbles or grain points and a minimum of the longitudinal lines left from the gumming machine. Some rolls of tape show a tendency to tear diagonally when sharply pulled. Such material should be avoided, or else carefully used to prevent an inconvenient spoilage of the transfer.

Backing Material—The pulled transfer may be placed on paper, nonadhesive cellophane, or on glass. The last two materials are used only when further reproductions of the transfer are to be made by printing, or when the records are to be used as lantern slides. For ordinary records, the transfers should be mounted on paper. Ordinary white typewriter paper is satisfactory, but should show no surface grain, water marks, or translucent spots. M660 weight or equivalent is convenient, since inked lines (as in a drawing) can be distinguished through a transfer backed by paper of this weight. Precision-ruled graph paper is sometimes useful as a backing material.

Other Equipment—Other articles, though not essential, will be found useful. These are a small pair of curved-blade scissors for shaping the cellophane tape, or a razor blade for cutting it to conform to surface breaks; broad-end tweezers for handling the tape; and a wooden stick or lead pencil for introducing the tape into interior surfaces.

Procedure for the Transfer Process—The part under examination must be free of oil or grease.

Transfers may be taken of indication patterns prepared by any magnetizing process. While the general method given here applies specifically to pattern due to the residual magnetism of the test specimen, it may easily be adapted to other methods.

Magnetize the piece under examination in a field so directed as to produce the pattern of the flaw to be recorded. Dip the specimen in the powder suspension or flow the suspension over the piece to develop the pattern.

If the process is used in conjunction with routine magnetic-particle inspection, the specimen should be well cleaned with cold CCl_4 after the defective areas are located and marked for identification. Allow the pattern to develop fully, but take care that excessive piling up of the powder on the indications does not occur. When the pattern is complete, remove the specimen and immediately pass through the washing solution. If the surface film of magnetic particle "soup" is allowed to dry before washing, a dark background to the print results. Remove the piece from the cleaning suspension and allow it to dry, holding it in

[6] U. S. Navy Aeronautical Standard M-361, Type TS.

such a position that quick, even drainage is had over the area to be recorded. When the surface is dry, blow lightly over the pattern to evaporate the last traces of liquid in the pattern lines. Do not blow across the wet surface to hasten evaporation, as this will cause a streaked background. Puddles or drops of cleaning solution, which may remain in the depressions or along metal edges, may be picked up by a piece of blotting paper. Care must be taken not to touch the area to be recorded, since every mark or disturbance of the surface coating will be faithfully picked up by the transfer tape.

When the pattern is dry, fix the specimen in a convenient position for working, cut a piece of transfer material large enough to cover the indication area, allowing enough in excess that the unavoidable finger or tweezer marks may be clipped off after the transfer is finished. It is well to extend the transfer tape so as to include the nearest break in the surface, which break will be recorded on the transfer to serve as an identification line, locating the indication with respect to the piece as a whole. If no such edge or break is conveniently near the indication, a line of identification may be drawn on the piece with ink or a soft lead pencil. These lines will be recorded by the transfer. Bring the transfer tape into firm contact with the surface of the specimen, adhesive side down, at some point outside of the indication area. When firm contact is made and there is no danger of the tape slipping, bring the rest of the transfer into contact with the metal surface, rolling it down with finger or thumb so that no air spaces are caused beneath it. When the transfer is in place, rub it down firmly but not too heavily, so that contact with the surface is complete and uniform. Rub out any air spaces and press firmly on the pattern lines. Then, when complete contact between the transfer and metal is had, remove the transfer tape by stripping it off from one end. Place it immediately on the backing material, rolling it down as before to prevent wrinkles and air spaces. Rub down well and cut to size, clipping off the stained ends of the transfer.

If the background of the record is too dark, reform the pattern without first rubbing off the surface of the specimen, and take a second transfer. This generally will reduce the background film of powder.

By manipulation, prints may be made of indications appearing on two or more planes, as for instance between the roots of the teeth and down the sides of a gear. It is more convenient and makes a more easily understood record, to make separate transfers from each plane and show these in their relation one to the other. To make prints of interior surfaces requires some practice, but prints can be made from such surfaces that are as clear and complete in detail as those taken from outside plane surfaces.

Quick Transfer Process—For use in shop-control work or where the superior appearance of the regular transfer process is not necessary, a quicker process may be used.

To make transfer records by the quick process, the magnetic particle inspection operation is performed by the regular production method to develop the indications which are to be recorded.

The surface is then dried by means of warm air from a hair drier. Care should be taken not to blow the indication out of shape by placing the hair drier too close to the area being dried. The hair drier dries off an indication area on an aircraft engine crankshaft in 2 or 3 min, after which the area is left to cool for 3 to 4 min before making a transfer. If the surface is too warm the adhesive on the transfer tape blurs the indication.

In order to dry the surface with the utmost speed, carbon tetrachloride may be carefully flowed over it, to wash off the magnetic-particle suspensoid. The CCl_4 dries rapidly after the suspensoid is carried off. By careful manipulation, this can be done without disturbing the indications. The expense for CCl_4 is high, but utmost speed is gained thereby.

The tape is applied and the transfer made the same as in the regular transfer process.

Dirty magnetic particle "soup" causes poor records by the quick process. The manner of flowing the "soup" over the part while magnetic-particle testing also affects the appearance, as does the position and manner of drying the surface.

Determination of Inclusions in Steels

SAE Recommended Practice

Report of Iron and Steel Division approved January 1941 and last revised October 1946. This SAE Recommended Practice conforms to ASTM E 45 – 42 T.

This method for rating inclusions is intended to cover alloy-steel and carbon-steel bars, billets, and slabs up to 10 in. wide by 5 in. thick, and special sections with the exception of sulfur-bearing types and all other free-machining steels. However, from the nature of this method, it could include all steel products.

Selection of Samples—The selection and preparation of samples is not specifically covered, but suggested as follows:

Where possible, the surface to be examined is ½ x 1 in., or ½ sq in. area.

When the cross-section of the sample to be classified is sufficiently large to permit (such as a 5 x 5-in. billet), the micro specimen is cut so that the face to be polished is in a center plane of the sample and is divided into two equal parts by a midway plane. A further requirement is that the ½-in. dimension be parallel to the longitudinal axis of the sample, that is, the direction of rolling.

When the sample to be classified is not of sufficient cross-section to permit the above method, for example a 2-in.-diameter

round bar, the specimen is cut so that again the ½-in. dimension is in the direction of rolling and the 1-in. dimension is a radius of a cross-section of the bar.

It is often desirable to facilitate polishing by hardening the specimen, quenching from above the Ac_3 range into the proper medium.

Polishing may be done by any desired technique. One generally followed is:

Step 1—Grind.

Step 2—Rough polish, going successively from No. 0, to No. 00, and No. 000 emery paper.

Step 3—Fine polish, employing some medium such as jeweler's rouge or levigated alumina.

Step 4—Wash in hot water and follow by rinsing in alcohol.

In the last polishing operation (Step 3), the direction of polish should be at right angles to the direction of rolling, since polishing scratches in the direction of rolling tend to confuse the appearance of the specimen.

The properly polished specimen is placed on the stage of a microscope and each individual field of the entire polished area is projected successively on a ground-glass screen at 100 diameters. The ground glass is ruled with a series of parallel lines which are ½ in. apart. The distance between any two parallel lines, namely ½ in. (equivalent to 0.005 in. on the specimen) is called a unit, in terms of which the lengths of inclusions are measured.

Classification—From the observations on the ground glass, the following three classifications are made in the sequence given:

1. *Longest Inclusion—Represented by a number which corresponds to the number of units which the inclusion covers on the screen.*

Fractional units are not used; the nearest whole unit is recorded. The width of the longest inclusion may be indicated by a suffix. This is illustrated by Fig. 1 and the following example:

Assume that the longest inclusion in each of two specimens is

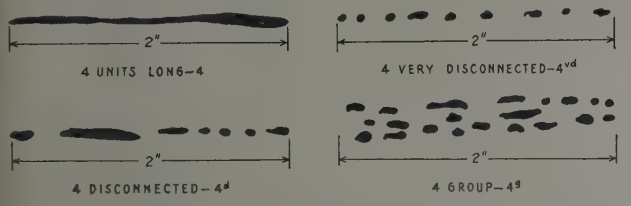


FIG. 1—DESIGNATION OF LENGTH AND WEIGHT OF INCLUSIONS (4 UNITS)

6 units in length. The difference in thickness may be denoted as 6^T, 6^H; other characteristics are designated by 6^d, 6^{vd}, and 6^g where ^{T} means thin (1 mm or less in width).

^{H} means heavy (3 mm or over in width).

^{d} means disconnected. (See Fig. 1.)

^{vd} means very disconnected. (See Fig. 1.)

^{g} means group. (See Fig. 1.)

A discontinuity of not less than 1 unit along the length of an inclusion being rated arbitrarily divides the inclusion into two inclusions, the largest of which, if it is the longest in the specimen, is rated as above, the smaller is included in the average inclusion as follows:

2. *Average Inclusion—The average length of all inclusions one unit and over in length, excluding the longest inclusion.*

This is also designated by a number equivalent to the number of units covered by the average length inclusion with a suffix indicating the number of inclusions rated in arriving at the average.

For example, and to continue the illustration above, the specimen rated as 6^T may have in addition two inclusions of 4 units length, one of 3 units length, and one of 1 unit length; its average rating would then be $(2 \times 4 + 3 + 1)$, or $12 \div 4$, or 3, and the full rating thus far would be $6^T - 3^4$.

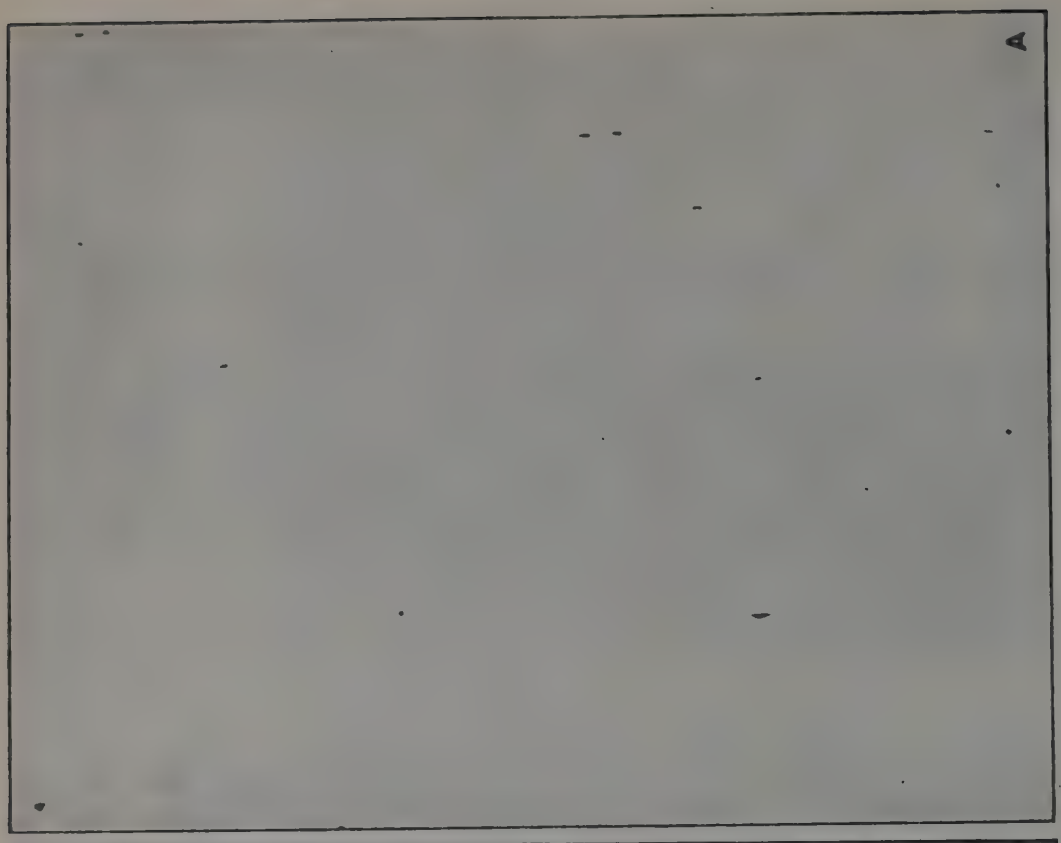
3. *Background—A rating designated by a letter and including all inclusions less than 1 unit in length.*

For example, the longest and the average length of inclusions in four specimens may be 6 and 1^3 respectively, but the background may be different. The ratings for these four specimens may be $6 - 1^3 - A$; $6 - 1^3 - B$; $6 - 1^3 - C$; $6 - 1^3 - D$; where the letters A, B, C, and D refer to the classification of background as depicted in Figs. 2, 3, 4, and 5.

Backgrounds—There is little difference of opinion between several observers as to the length of the longest and the average inclusions. There may be some difference of opinion regarding the background. Accordingly, it is necessary that designations of background quality be on a common basis, for which purpose the accompanying standard pictures are provided. If more exacting classification of background is desired, it can be made by using plus or minus signs after the background letter.

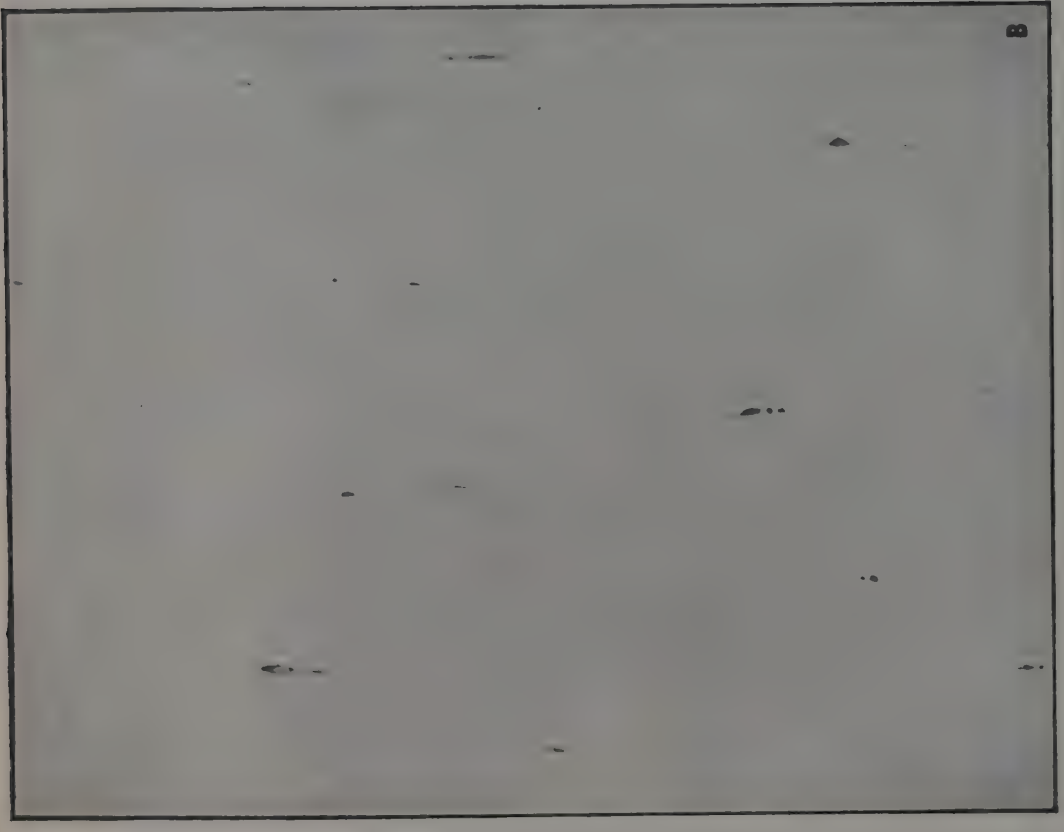
General Form of Rating—It is apparent then that the general form of rating will be, say $7 - 2^3 - B$: meaning that the largest inclusion in the specimen is of 7 units length, that all other inclusions are three in number with an average length of 2 units, and that the background of the specimen may be represented by Background Classification B (Fig. 3). It should be apparent also that the least rating the method will allow will be $0 - 0 - A$.

(*Figs. 2–5 begin on next page.*)



A

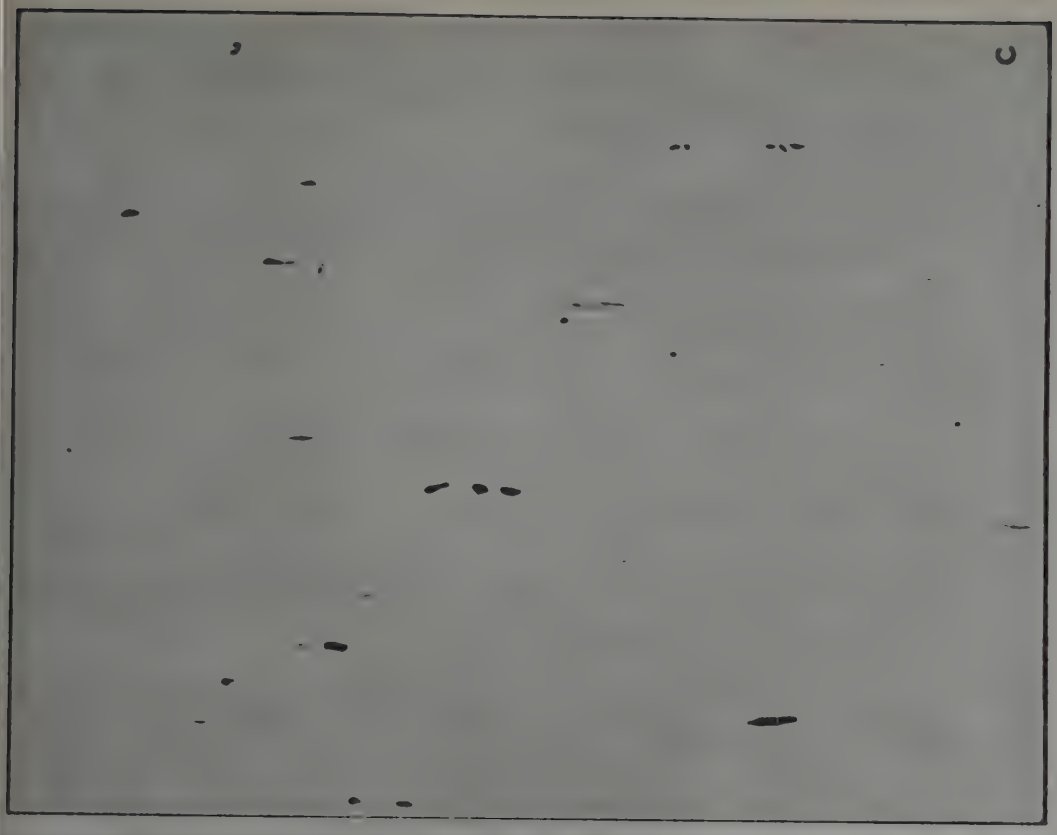
FIG. 2—BACKGROUND CLASSIFICATION A (MAGNIFICATION IS 100×)



B

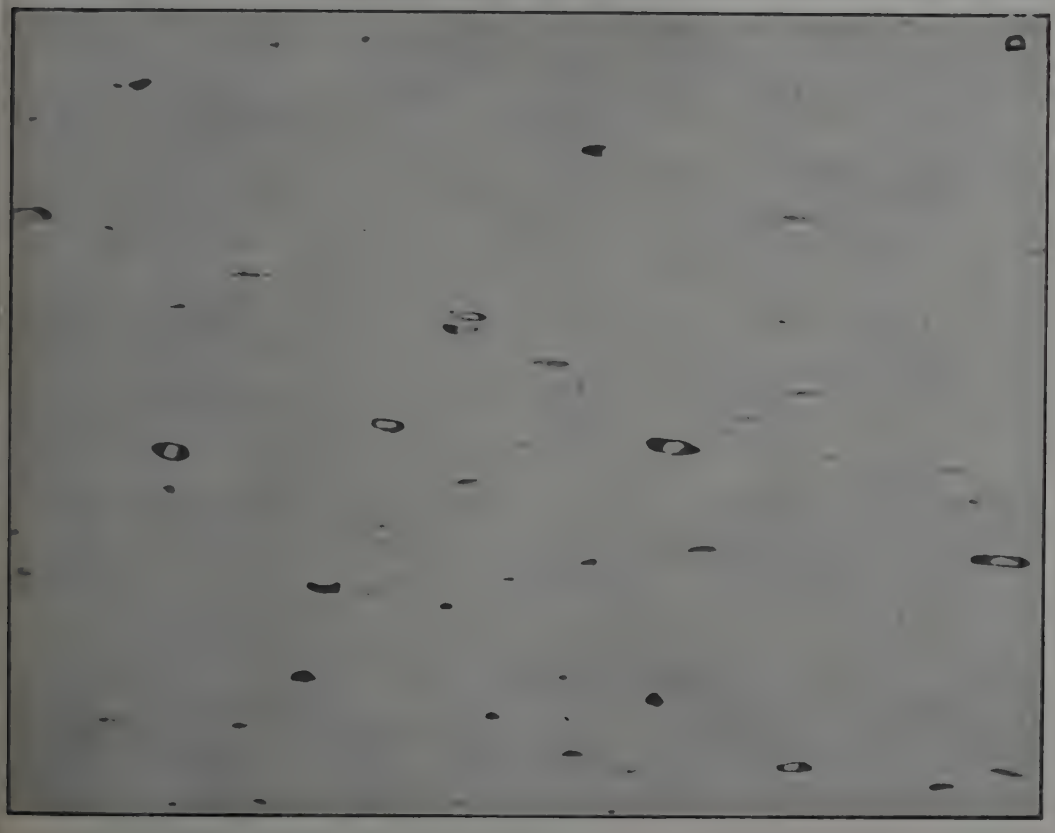
FIG. 3—BACKGROUND CLASSIFICATION B (MAGNIFICATION IS 100×)

(*Continued on next page.*)



C

FIG. 4—BACKGROUND CLASSIFICATION C (MAGNIFICATION IS 100×)



D

FIG. 5—BACKGROUND CLASSIFICATION D (MAGNIFICATION IS 100×)

Methods of Measuring Case Depth

SAE Recommended Practice

Report of Iron and Steel Technical Committee approved January 1950.

Methods Applicable to Carburizing Grades of Steel

Definitions for Carburized Cases—*Effective case depth* is the distance (measured perpendicularly) from the surface of a hardened case to a point of hardness equivalent to Rockwell C 50. *Total case depth* is the distance (measured perpendicularly) from the surface of the case down through carbon enrichment.

Microscopic Method for Carbon and Alloy Steels in the Hardened Condition

1. Fracture or cut specimen at right angles to the surface.
2. Give full microscopic polish to specimen.
3. Etch in 3 to 5% nital (by volume at room temperature).
4. For approximate effective-case-depth measurement, read to 50% martensite at 100 diameters (×100).

Microscopic Method for Plain Carbon Steels in the Annealed[1] Condition

1. Fracture or cut specimen at right angles to the surface.
2. Specimen may be protected by coating of copper, other protective coating, or any suitable means of preventing loss of carbon.
3. Pack in charcoal in small thin-wall container.
4. Place container in furnace operating at 1650–1700 F.
5. Leave in furnace long enough for specimen to reach uniform furnace temperature.
6. Remove container from furnace and cool in some retarding medium such as mica, lime, or other non-carbonaceous insulating material at a rate which will reduce temperature to 800 F in 2½ to 3 hr. Cool as desired from 800 F.
7. Prepare specimen for microscope.
8. Etch in 3% nital (by volume at room temperature). Examine at 100 diameters.
9. For approximate effective-case-depth measurement, read down to 50% pearlite-ferrite combination point.
10. For total-case-depth measurement, read the depth of carbon enrichment.

Microscopic Method for Alloy Steels in the Annealed[1,2] Condition

1. Fracture or cut specimen at right angles to the surface.
2. Specimen may be protected by coating of copper, other protective coating, or any suitable means of preventing loss of carbon.
3. Pack in charcoal in small thin-wall container.
4. Place container in furnace operating at 75–150 F above the upper critical temperature (Ac_3) for the core. (Generally, an annealing temperature of 1600–1675 F should be satisfactory.)
5. Leave in furnace long enough for specimen to reach uniform furnace temperature.
6. Remove container from furnace and transform isothermally or cool at a sufficiently slow rate to insure maximum ferrite separation to 0.50% carbon level. If martensite is retained in the structure and it is desired to increase the contrast of the case, the specimen may be tempered at 1000–1100 F and cooled as desired.
7. Prepare specimen for microscope.
8. Etch in 3 to 5% nital (by volume at room temperature). Examine at 100 diameters.
9. For approximate effective-case-depth measurement, read down to 50% pearlite-ferrite combination point.
10. For total-case-depth measurement, read the depth of carbon enrichment.

Ms (Martensite-Start) Method for Alloy Steels in the Annealed Condition—This is an alternate method of measuring case depth by martensite formation.[3]

Brinell Glass Method—This method is recommended for routine production control or for laboratory use when properly correlated with more precise methods for both plain carbon or alloy steels in the hardened condition.

1. Prepare specimen by fracturing or cutting at right angles to the surface.
2. Follow either of the following methods:

(a) Rough grind specimen and etch for 10 sec in a solution containing 50 cc of concentrated nitric acid, 5 g of ammonium persulfate, and 50 cc of water. Then swab, rinse, and dry specimen prior to re-etching in 10% nital. Examine with a Brinell microscope. Read all of the blue (darkened zone) for total case.

(b) Grind or polish on No. 000 or finer metallographic emery paper or both. Etch specimen in fresh 5% solution of nitric acid in ethyl alcohol at 70–80 F for approximately 1 min, agitating continuously. Then rinse in two clean ethyl alcohol rinses. For total-case-depth measurement, read all of the darkened zone. For approximate effective-case-depth measurement, read from the external surface of the specimen to the center of the inner dark band produced by etching.

Fracture Method—This is recommended chiefly as a production-control method of measuring case depth of carburizing grades of steel.

1. Notch the specimen and fracture.
2. Etch in 3 to 5% nital or heat tint (blue) the fractured surface at 600 F.
3. Read with a Brinell glass to a depth previously correlated with more precise methods.

Step-Grind Method[4]—This is recommended as a production-control method of measuring effective case depth of carburizing grades of steel.

1. Use a specimen of steel ½ x ⅝ x 2 in. long of a known core hardness of Rockwell C 30-35 after oil quenching.
2. Load test bars at regular intervals with parts to be carburized and hardened.
3. Place hardened test bar in a suitable vise on a surface grinder and grind two flats of required depth for case desired. A grinding wheel ½ in. wide by 7 in. in diameter of grade 58A-80-H-14-V-55 is recommended. Use surface grinds of 0.0005 in. depth per travel of the work table.
4. Check Rockwell C hardness of the ground flats. The first

[1] Care should be taken in annealing, since the line of demarcation may be altered by diffusion.

[2] This method becomes less effective as the alloy content increases.

[3] For further information, see Transactions of American Society for Metals, Vol. 33, 1944, pp. 261–275: "Martensite Reactions in Alloy Steels" by P. Payson and C. H. Savage; and Vol. 37, 1946, pp. 27–47: "The Application of Ms Points to Case Depth Measurement" by E. S. Rowland and S. R. Lyle.

[4] In all cases, the surface hardness of the hardened test bar is taken to serve as a guide on the type of case being produced. In other words, if the case is too rich or the surface carbon is depleted, then hardness will be several Rockwell C points below the hardness taken at a depth below the surface.

TABLE 1—*Empirical Guide for Depth of Grinds on Test Bars for Required Effective Case*

REQUIRED EFFECTIVE CASE, IN.	AMOUNT GROUND OFF	
	First grind, C 57 minimum, in.	Second grind, C 50 maximum, in.
0.015 ± 0.005	0.000	0.015
0.020 ± 0.005	0.005	0.020
0.025 ± 0.005	0.010	0.025
0.030 ± 0.005	0.015	0.030
0.040 ± 0.005	0.025	0.040
0.060 ± 0.005	0.045	0.060

ground flat should check Rockwell C 57-58 minimum while the second ground flat should check Rockwell C 50 maximum.

5. Follow Table 1 for depth of grinds on test bars for required effective case.

[5] "Dry cyaniding," "gas cyaniding," and "carbonitriding" refer to the hydrocarbon ammonia-gas processes.
The process produces a case quite similar to that produced by cyaniding. The outer white layer may not be as pronounced and there may be considerable austenitic structure. These cases are read as described for cyanided steels.

Methods Applicable to Cyanided[5] Grades of Steel

Microscopic Method

1. Fracture or cut specimen at right angles to the surface.
2. Give full microscopic polish to specimen.
3. Etch in 3 to 5% nital (by volume at room temperature).
4. The usual cyanide case contains a light etching layer followed by a total martensitic constituent, which in turn is followed by martensite with increasing networks of other constituents, depending on the type of steel which has been cyanided. The total case is easily read when steels of low carbon content have been used and when the quenching temperature has been such that considerable ferrite is left in the region immediately below the case. *These cases may be read to the bottom of the solid constituents and to the end of the fingers which extend into the core material.* When the material cyanided is such that total martensite occurs immediately below the case, greater difficulty is encountered. At times, a fairly sharp line of demarcation can be noticed. When such is not present, the use of hardness tests such as described under the heading "Methods Applicable to Nitrided Grades of Steel" is recommended.

(*Continued on next page.*)

Hardness Traverse Method

This method is considered the most accurate for effective-case-depth measurement.

1. Cut specimen perpendicular to carburized surface from part to be examined.
2. Grind and polish specimen. Surface finish of the area to be traversed should be polished finely enough so as not to affect the hardness impressions—that is, the lighter the indentor load, the finer the polish necessary.
3. For effective-case-depth measurement, read to a point of hardness equivalent to Rockwell C 50. A plot of hardness versus depth from the surface will facilitate this reading. Figs. 1–4 illustrate the recommended procedures.

Taper-Grind Procedure—This procedure, illustrated by Fig. 1, is recommended for measurement of light and medium cases.

A shallow taper is ground through the case, and hardness measurements are made along the surface thus prepared. The angle is chosen such that readings spaced equal distances apart will represent the hardness at the desired increments below the surface of the case.

Unless special anvils are used, a parallel section should be prepared so that readings are taken at right angles to the surface. Care should be exercised in grinding to prevent tempering.

Step-Grind Procedure—This procedure, illustrated by Fig. 2, is recommended for measurement of medium and heavy cases.

It is essentially the same as the taper-grind section method with the exception that hardness readings are made on steps which are known distances below the surface.

Cross-Section Procedures—The procedure illustrated by Fig. 3 is recommended for the measurement of light, medium, and heavy cases. The alternate procedure, illustrated by Fig. 4, is recommended for heavy cases.

The hardness traverse should be started far enough below the surface to ensure proper support from the metal between the center of the impression and the surface. Subsequent impressions are spaced far enough apart so as not to distort one another. The distance from the surface of the case to the center of the impression is measured on a microscope.

Hardness Testers—Those which use light indentor loads (for example, Tukon, Eberbach, and Vickers) are recommended for all of the above procedures. Testers using heavier loads (for example, Rockwell Superficial, Rockwell A, or Rockwell C) may be used for medium and heavy case measurements.

FIG. 1—SPECIMEN FOR TAPER-GRIND PROCEDURE

FIG. 2—SPECIMEN FOR STEP-GRIND PROCEDURE

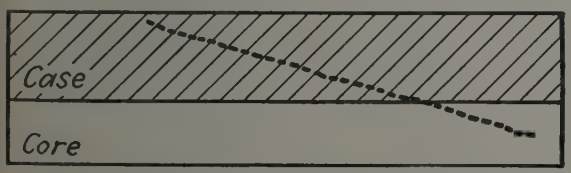


FIG. 3—SPECIMEN FOR CROSS-SECTION PROCEDURE

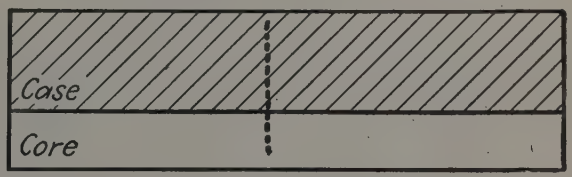


FIG. 4—SPECIMEN FOR ALTERNATE CROSS-SECTION PROCEDURE

Methods Applicable to Nitrided Grades of Steel

Hardness Traverse Method—This method, described in the accompanying box, is recommended as the most accurate for the measurement of this type of case.

Microscopic Method

1. Fracture or cut specimen at right angles to the surface.
2. Give full microscopic polish to specimen.
3. Etch with the following reagent:

10 parts of 4% picral
1 part of 4% nital

This reagent delineates the high-nitrogen layers on the surface and the iron nitride network constituent within the case.

4. It is more difficult to read nitride case depth microscopically than it is to read carbide case depth, since the gradual diminution of nitride network constituent makes it almost impossible to determine exactly where the case ends.

Fracture Method—The depth of nitride case can be determined by examining the surface of a fracture through the case. However, this method is very rough and is recommended only for those instances where the crudest type of measurement is desired.

Methods Applicable to Flame-Hardened and Induction-Hardened Areas of Steel

Microscopic Method

1. Cut specimen at right angles to the surface.
2. Give full microscopic polish to specimen.
3. Etch in 5% nitric acid in denatured alcohol for 4 min. Agitate while etching.
4. Measure depth of fully martensitic structure. This is considered the fully hardened case depth. Continue microscopic exploration until the base-metal structure is reached. The distance between the full martensitic area and the base metal is referred to as the "transition zone."

Macroscopic Method

1. Cut sample at right angles to the surface.
2. Grind sample to a finish equivalent to No. 000 metallographic emery paper.
3. Etch in Solution No. 1 composed of 5% concentrated nitric acid in denatured alcohol for 4 min. Agitate while etching. Transfer to Solution No. 2 composed of 10% concentrated hydrochloric acid in denatured alcohol for 8 min. Agitate while etching. Transfer to Solution No. 3 composed of 15% ammonium hydroxide in denatured alcohol for 4 min. Agitate while in solution.
4. Rinse and dry for observation.
5. Measure depth with a Brinell glass down to the line of demarcation between hardened surface and core.

Macroscopic Method for Use When Saw Cutting is Necessary

1. Temper part at approximately 950 F.
2. Saw section to be examined.
3. Grind to a finish equivalent to No. 0 metallographic emery paper.[6]
4. Etch in ammonium persulfate.
5. Rinse in water; swab to remove any smudge.
6. Rinse in hot water and dry.
7. Measure depth with a Brinell glass down to the line of demarcation between hardened surface and core.

Hardness Traverse Method—A transverse hardness traverse check such as recommended for deep carburized cases may be used.

[6] For large sections, careful surface grinding with frequent dressing of the wheel is satisfactory.

Physical Requirements for Bolts, Capscrews, Studs, and Nuts

SAE Recommended Practice

Report of Iron and Steel Technical Committee approved January 1949 and corrected October 1949.

Scope—These specifications cover the physical requirements for bolts, capscrews, studs, and nuts used in the automotive and allied industries. Wherever the term "bolt" is used, it is understood to include capscrews and similar externally threaded fasteners.

General Data—To cover adequately the requirements for bolts, seven grades are included:

Grade 1—commercial bolts.

Grade 2—low-carbon bolts.

Grade 3—medium-carbon, cold-worked, hexagon-head bolts and studs.

Grade 4—medium-carbon, cold-worked studs (studs only).

Grade 5—medium-carbon, quenched-and-tempered bolts.

Grade 6—medium-carbon, quenched-and-tempered, high-strength bolts.

Grade 7—medium-carbon alloy, quenched-and-tempered bolts.

For Grade 1 commercial bolts and all nuts, open-hearth, electric-furnace, or Bessemer steel may be used. For all other grades, open-hearth or electric-furnace steel shall be used. Grades 3 and 4 are listed to include studs, but studs may be specified under any of the grades.

Grades and Requirements—The various grades and their requirements are shown in Table 1. The following additional requirements apply:

Wedge Test for Bolts and Capscrews—Products such as bolts and capscrews shall be subjected to a wedge test, the details of which are given under Methods of Testing.

Stripping Test for Nuts—The nuts furnished for each grade shall meet the minimum requirements for tensile strength of bolt specified without failure in the stripping test. The stripping test is described under Methods of Testing. This test does not apply to nuts which are not expected to withstand the strength of the bolts, such as jam nuts, slotted nuts, and castle nuts.

Methods of Testing—*Tension Test*—Tension tests shall be made on the finished bolt or stud. The load shall be applied between the head and a nut or suitable fixture, either of which shall have sufficient thread engagement to develop the full strength of the bolt. The nut or fixture shall be assembled on the bolt, leaving three complete bolt threads exposed and unengaged between the grips. The nut or fixture shall be assembled freely to the thread runout and then unscrewed three full turns. If failure occurs by thread stripping before reaching the minimum required tensile load, the individual test shall be discarded.

Where the bolt or thread length is too short for a tension test, acceptance shall be determined by the hardness range specified in Table 1.

The tensile-strength determination shall be based on the cross-sectional area of the bolt where the break occurs. When the break occurs in the threaded portion, the cross-sectional area shall be taken from Table 2. For sizes not included in Table 2, the area shall be calculated from the following formula:

$$A = 3.1416\left(\frac{P+R}{4}\right)^2$$

TABLE 1—*Requirements for Grades of Bolts and Studs*[a]

BOLT AND STUD SIZES	MINIMUM TENSILE STRENGTH, PSI	PROOF LOAD, PSI	HARDNESS	
			Brinell	Rockwell
Grade 1—Commercial Bolts	55,000	—	207 max	B95 max
Grade 2—Low-Carbon Bolts				
Up to ½ in., inclusive	68,000	—	241 max	B100 max
Over ½ to ¾ in., inclusive	64,000	—	241 max	B100 max
Grade 3—Medium-Carbon, Cold-Worked, Hexagon-Head Bolts and Studs				
Up to ½ in., inclusive	110,000	85,000	207–269	B95–B104
Over ½ to ⅝ in., inclusive	100,000	80,000	207–269	B95–B104
Grade 4—Medium-Carbon, Cold-Worked Studs				
Up to ½ in., inclusive	120,000	95,000	217–269	B96–B104
Over ½ to ⅝ in., inclusive	110,000	88,000	217–269	B96–B104
Grade 5—Medium-Carbon, Quenched-and-Tempered Bolts				
Up to ½ in., inclusive	125,000	90,000	255–321	C25–C34
Over ½ to ¾ in., inclusive	120,000	85,000	255–321	C25–C34
Over ¾ to 1 in., inclusive	110,000	78,000	223–285	C19–C30
Over 1 to 1½ in., inclusive	105,000	74,000	223–285	C19–C30
Grade 6—Medium-Carbon, Quenched-and-Tempered, High-Strength Bolts				
Up to ⅝ in., inclusive	140,000	110,000	285–331	C30–C36
Over ⅝ to ¾ in., inclusive	133,000	105,000	269–331	C28–C36
Grade 7—Medium-Carbon Alloy, Quenched-and-Tempered Bolts				
Up to ½ in., inclusive	150,000	120,000	302–352	C32–C38
Over ½ to 1 in., inclusive	140,000	110,000	285–352	C30–C38
Over 1 to 1½ in., inclusive	125,000	95,000	255–321	C25–C34

[a] Nuts must meet minimum tensile requirements of bolts.

where A = mean equivalent area (stress area)
P = mean pitch diameter
R = mean root diameter

Elastic Proof Load—In determining conformity to specifications for proof load, the overall length of a straight sample bolt or stud shall be measured at the true centerline. The preferred method of measuring the length shall be between conical centers on the centerline of the part using mating centers on the meas-

TABLE 2—*Stress Areas (Mean Equivalent Areas) and Threads per Inch*

BOLT DIAMETER	COARSE THREAD		FINE THREAD	
	Stress area, sq in.	Threads per inch	Stress area, sq in.	Threads per inch
¼	0.0317	20	0.0362	28
5/16	0.0522	18	0.0579	24
⅜	0.0773	16	0.0876	24
7/16	0.1060	14	0.1185	20
½	0.1416	13	0.1597	20
9/16	0.1816	12	0.2026	18
⅝	0.2256	11	0.2555	18
¾	0.3340	10	0.3724	16
⅞	0.4612	9	0.5088	14
1	0.6051	8	0.6624	12
1⅛	0.7627	7	0.8549	12
1¼	0.9684	7	1.0721	12
1⅜	1.1538	6	1.3137	12
1½	1.4041	6	1.5799	12

uring anvils. Other recognized methods may be used such as ball-point anvils on prepared surfaces at the true centerline. The sample part shall be marked so that it can be placed in the measuring fixture in the same position for all measurements. The measuring instrument shall be capable of measurement to 0.0001 in. The part shall then be loaded as in the tensile-strength test to load equal to the specified elastic-proof load, then removed from the testing machine and its overall length again determined. The length after loading shall not exceed that before loading by more than 0.0005 in.

Hardness Test—Hardness requirements will be waived provided the other requirements of the specification are met.

The hardness shall be measured on a transverse section through the threaded portion of the bolt at a point one quarter of the nominal diameter from the axis of the bolt. This section shall be taken one diameter from the end of the bolt. Either the Brinell or Rockwell method of hardness testing may be used.

Wedge Test—The bolt shall be subjected to the proof load shown in Table 1. Then a 10-deg wedge shall be placed under the head of the bolt and the tensile test continued until failure. To meet the requirements of this test, there must be a tensile failure in the body or threads with no fracture of the head. The bolt shall meet the requirement for minimum tensile strength shown in Table 1 without failure.

Stripping Test for Nuts—The sample nut shall be assembled on a hardened, threaded mandrel and the load specified in Table 3 applied to the nut. Threads of the nut shall not strip at this load. If the threads of the mandrel are damaged during the test, the test shall be discarded.

The mandrel shall be threaded to the American Standard Class 3 tolerance, except that the major diameter shall be the minimum major diameter with a plus tolerance of 0.002 in.

If the unit tensile stress developed in the mandrel is required, the loads thus obtained shall be divided by the mean thread area as given in Table 2.

Number of Tests—The requirements of these specifications are those met in continuous mass-production for stock during which the manufacturer has made such sample inspections as to insure normally that the material is controlled within the specified limits.

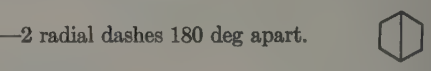
Three bolts may be selected for tension test from each lot of bolts, and three nuts may be selected for stripping test from each lot of nuts.

A lot of bolts or nuts or both shall consist of 25,000 or fraction thereof for diameters ¼ to ⅜ in. inclusive, 15,000 or fraction thereof for diameters over ⅜ to ⅝ in. inclusive, 5000 or fraction thereof for diameters over ⅝ to 1 in. inclusive, and 2500 or fraction thereof for diameters over 1 in.

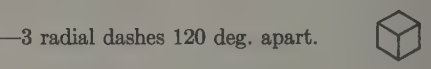
Retest—Should any sample from the same lot fail to meet the requirements of a specified test, twice the number of samples shall be tested, in which case all of the additional samples shall meet the specifications.

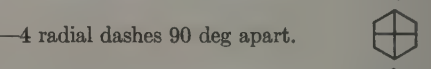
Identification—Bolt heads shall be marked to identify the manufacturer. The following bolt head markings are prescribed:

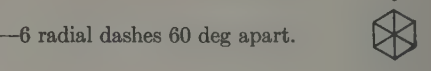
Grades 1 and 2—No marking.

Grade 3—2 radial dashes 180 deg apart. 

Grade 4—No marking.

Grade 5—3 radial dashes 120 deg. apart. 

Grade 6—4 radial dashes 90 deg apart. 

Grade 7—6 radial dashes 60 deg apart. 

(*Continued on next page.*)

TABLE 3—*Proof Loads and Minimum Tensile Strengths as Calculated from Stress Areas Given in Table 2*

GRADE	BOLT AND STUD DIAMETER, IN	COARSE THREAD		FINE THREAD	
		Proof load, lb	Minimum tensile strength, lb	Proof load, lb	Minimum tensile strength, lb
Grade 1—Commercial Bolts	1/4	—	1,740	—	1,990
	5/16	—	2,870	—	3,185
	3/8	—	4,250	—	4,820
	7/16	—	5,830	—	6,515
	1/2	—	7,790	—	8,785
	9/16	—	9,990	—	11,145
	5/8	—	12,410	—	14,050
	3/4	—	18,370	—	20,480
	7/8	—	25,370	—	27,985
	1	—	33,280	—	36,430
	1 1/8	—	41,950	—	47,020
	1 1/4	—	53,260	—	58,965
	1 3/8	—	63,460	—	72,255
	1 1/2	—	77,230	—	86,895
Grade 2—Low-Carbon Bolts	1/4	—	2,155	—	2,460
	5/16	—	3,550	—	3,935
	3/8	—	5,255	—	5,955
	7/16	—	7,210	—	8,060
	1/2	—	9,630	—	10,860
	9/16	—	11,620	—	12,965
	5/8	—	14,440	—	16,350
	3/4	—	21,380	—	23,835
Grade 3—Medium-Carbon, Cold-Worked, Hexagon-Head Bolts and Studs	1/4	2,695	3,485	3,075	3,980
	5/16	4,435	5,740	4,920	6,370
	3/8	6,570	8,505	7,445	9,635
	7/16	9,010	11,660	10,070	13,035
	1/2	12,035	15,575	13,575	17,565
	9/16	14,530	18,160	16,210	20,260
	5/8	18,050	22,560	20,440	25,550
Grade 4—Medium-Carbon, Cold-Worked Studs	1/4	3,010	3,805	3,940	4,345
	5/16	4,960	6,265	5,500	6,950
	3/8	7,345	9,275	8,320	10,510
	7/16	10,070	12,720	11,255	14,220
	1/2	13,450	16,990	15,170	19,165
	9/16	15,980	19,975	17,830	22,285
	5/8	19,850	24,815	22,485	28,105
Grade 5—Medium-Carbon, Quenched-and-Tempered Bolts	1/4	2,855	3,960	3,260	4,525
	5/16	4,700	6,525	5,210	7,235
	3/8	6,955	9,660	7,885	10,950
	7/16	9,540	13,250	10,665	14,810
	1/2	12,745	17,700	14,375	19,960
	9/16	15,435	21,790	17,220	24,310
	5/8	19,175	27,070	21,715	30,660
	3/4	28,390	40,080	31,655	44,690
	7/8	35,975	50,730	39,685	55,970
	1	47,195	66,560	51,665	72,865
	1 1/8	56,440	80,085	63,260	89,765
	1 1/4	71,660	101,680	79,335	112,570
	1 3/8	85,380	121,150	97,215	137,940
	1 1/2	103,905	147,430	116,910	165,890
Grade 6—Medium-Carbon, Quenched-and-Tempered, High-Strength Bolts	1/4	3,485	4,440	3,980	5,070
	5/16	5,740	7,310	6,370	8,105
	3/8	8,500	10,820	9,635	12,265
	7/16	11,660	14,840	13,035	16,590
	1/2	15,575	19,825	17,565	22,360
	9/16	19,975	25,425	22,285	28,365
	5/8	24,815	31,585	28,105	35,770
	3/4	35,070	44,420	39,100	49,530
Grade 7—Medium-Carbon Alloy, Quenched-and-Tempered Bolts	1/4	3,805	4,755	4,345	5,430
	5/16	6,265	7,830	6,950	8,685
	3/8	9,275	11,595	10,510	13,140
	7/16	12,720	15,900	14,220	17,775
	1/2	16,990	21,240	19,165	23,955
	9/16	19,975	25,425	22,285	28,365
	5/8	24,815	31,585	28,105	35,770
	3/4	36,740	46,760	40,965	52,135
	7/8	50,730	64,570	55,970	71,230
	1	66,560	84,715	72,865	92,735
	1 1/8	72,455	95,335	81,215	106,860
	1 1/4	92,000	121,050	101,850	134,010
	1 3/8	109,610	144,225	124,800	164,210
	1 1/2	133,390	175,510	150,090	197,490

Automotive Gray Iron Castings — SAE Standard

Report of Iron and Steel Division approved January 1935 and last revised by Iron and Steel Technical Committee January 1949.

Scope—These specifications cover iron castings used in automotive and allied industries.

Workmanship and Finish—Castings shall represent good foundry practice, shall be smooth and clean, and shall be free from injurious flaws and defects. In other respects, the castings shall conform to special requirements agreed to by the supplier and purchaser.

Machinability—Castings shall machine satisfactorily.

Physical Properties and Tests—*Hardness Tests*—Hardness shall be taken near the fracture on broken halves of arbitration bars. Test bars must receive the same thermal treatment as castings. By agreement between supplier and purchaser, hardnesses may be specified at definite locations on castings.

Transverse Tests—Transverse tests are to be made on arbitration bars (Fig. 1 and Table 1) cast separately according to ASTM A 48, which states that test bars shall be cast from the ladles of iron used to pour the castings. In the case of slightly elliptical bars, loading shall be on the minimum diameter, and the correction factor for size shall be obtained as follows: Square the depth of the bar measured at the point of application of the original load, multiply by the width, and divide the product by the cube of the diameter of the standard or nominal-size bar. In all cases, controlling dimensions shall be the diameter of the bar at the fracture. In case the size of the bar is not specified, the 1.2-in.-diameter bar shall be used. The values shown in Table 2 are for the 1.2-in.-diameter bar.

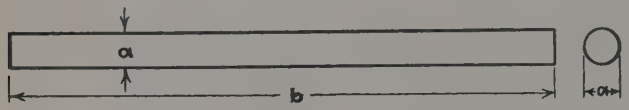


FIG. 1—TRANSVERSE-TEST SPECIMEN

TABLE 1—*Dimensions of Transverse-Test Specimens*

TRANSVERSE-TEST SPECIMEN	*a*, DIAMETER, IN.	*b*, LENGTH, IN.	DISTANCE BETWEEN SUPPORTS, IN.
A	0.875	15	12
B	1.20	21	18
C	2.00	27	24

TABLE 2—*Physical Properties*[a] *of Automotive-Type Cast Iron*

SAE No.	BRINELL HARDNESS NO.	MINIMUM TRANSVERSE LOAD, LB	MINIMUM DEFLECTION, IN.	MINIMUM TENSILE STRENGTH, PSI
110	187 max	1800	0.15	20,000
111	170–223	2200	0.20	30,000
120	187–241	2400	0.24	35,000
121	202–255	2600	0.27	40,000
122	217–269	2800	0.30	45,000

[a] Properties determined from arbitration test bar (1.2-in. diameter as-cast or stress relieved at 1050 F max).

Tension Test—Tension-test specimens are to be machined from arbitration bars and tested in accordance with ASTM A 48 which is substantially as follows: The tension-test specimens shall be machined from the transverse test bars to the dimensions shown in Fig. 2 and Table 3. By agreement between purchaser and supplier, tension-test specimens may be taken from the casting at specified locations. Tension tests taken from castings may not agree with tests taken from test bars even though cooling rates are similar. Proximity to heavy or light sections may cause unsoundness.

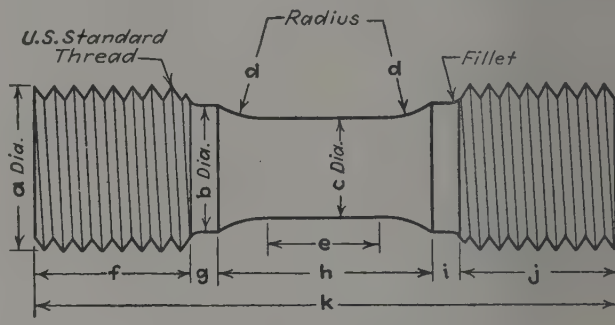


FIG. 2—TENSION-TEST SPECIMEN

TABLE 3—*Dimensions of Tension-Test Specimens*

TENSION-TEST SPECIMEN	*a*	*b*	*c*	*d*	MIN *e*[a]	*f*	*g*	MIN *h*	*i*	*j*	MIN *k*
A	3/4	5/8	0.505	1.00	0.505	1.00	0.25	1.25	0.25	1.00	3.7
B	1 1/8	15/16	0.750	1.00	0.750	1.00	0.25	1.50	0.25	1.00	4.0
C	1 7/8	1 7/16	1.25	2.00	1.25	1 3/4	5/16	2 1/4	5/16	1 3/4	6 3/8

[a] Length of parallel.

Suggested Usage

SAE 110—miscellaneous soft iron castings (as-cast or annealed) in which strength is not of primary consideration. Exhaust manifolds may be made of this grade of iron alloyed or unalloyed.

SAE 111—small cylinder blocks, cylinder heads, aircooled cylinders, pistons, clutch plates, oil-pump bodies, transmission cases, gear boxes, clutch housings, and light-weight brake drums.

SAE 113—brake drums and clutch plates for moderate service requirements where high-carbon iron is desired and heat checking is a problem. (See Table 4.)

SAE 114—heavy-duty drums and clutch plates where both heat checking and strength are definite requirements. Since the same base iron is indicated for both SAE 113 and SAE 114, it is presumed that alloys will be used especially in the latter to meet the strength and structural requirements. (See Table 4.)

SAE 120—automobile cylinder blocks, cylinder heads, flywheels, truck brake drums, cylinder sleeves, cylinder liners, and pistons.

SAE 121—truck and tractor cylinder blocks and heads, heavy flywheels, tractor transmission cases, differential carrier castings, heavy gear boxes.

SAE 122—diesel-engine castings, liners, cylinders, and pistons and heavy parts in general.

Compositions—The analyses shown in Table 5 are not to be

TABLE 4—*Chemical, Physical, and Structural Requirements of Automotive Gray Iron Castings for Brake Drums and Clutch Plates*

	SAE 113	SAE 114
Chemical Composition, %		
Carbon, total (mandatory)	3.40 min	3.40 min
Silicon (as desired)	1.10–1.70	1.10–1.70
Manganese (as desired)	0.60–0.90	0.60–0.90
Sulfur (typical)	0.14	0.14
Phosphorus (typical)	0.20	0.20
Alloys	As required	As required
Physical Properties		
Hardness, Bhn	179–229	207–269
Min transverse load, lb	2200	2600
Min deflection, in.	0.20	0.27
Min tensile, psi	30,000	40,000
Structural Properties		
Graphite	Type A, Size 2–4.	Type A, Size 3–5.
Matrix	Lamellar pearlite with ferrite if present not to exceed 15% approximate.	Fine lamellar pearlite with excess constitutent, free cementite or free ferrite, or both not to exceed 5% approximate.

construed as required or sufficient. In some cases, it may be desirable to use alloying elements to obtain the specific service requirements demanded. The kind and amount of the alloying constituents used should be a matter of agreement between the supplier and the purchaser.

When alloying elements are specified, Table 6 gives the practical range for commercial limits. By agreement between supplier and purchaser, closer or wider limits than shown in Table 6 are acceptable.

TABLE 5—*Typical Base Compositions*[a] *(Not to be Construed as Required or Sufficient)*

SAE No.	TOTAL C, %	Si, %	Mn, %	S, %	P, %
110	3.40 3.70	2.80 2.30	0.50–0.80	0.12	0.25
111	3.25 3.50	2.30 2.00	0.60–0.90	0.12	0.20
120	3.20 3.40	2.20 1.90	0.60–0.90	0.12	0.15
121	3.10 3.30	2.10 1.80	0.60–0.90	0.12	0.12
122	3.00 3.20	2.10 1.80	0.70–1.00	0.10	0.10

[a] These suggestions are offered in the hope that the producer will guard against either the low side or the high side for both carbon and silicon. If one is on the high side, the other should be low.

TABLE 6—*Residual and Alloy Ranges*

	Ni	Mo	Cr	Cu	V
Permissible Residuals, Base Iron, %	0–0.20	0–0.08	0–0.10	0–0.20	0–0.03
Recommended Ranges for Specification from Mean Specified Alloy Content, % plus or minus	0.15	0.075	0.10	0.10	0.03

Automotive Malleable Iron Castings

SAE Standard

Report of Iron and Steel Division approved June 1911 and last revised by Iron and Steel Technical Committee January 1949. This SAE Standard conforms to ASTM A 47.

Scope—These specifications cover malleable iron castings for general automotive, agricultural-implement, railroad, and general machinery purposes.

Process—The castings shall be produced by either the air-furnace, open-hearth, or electric-furnace process.

Castings shall be free from primary graphite.

Physical Properties and Tests—*Tensile Tests*—The tensile-test specimens specified shall conform to the minimum tensile-property requirements shown in Table 1.

TABLE 1—*Minimum Physical-Property Requirements for Automotive Malleable Iron Castings*

PHYSICAL PROPERTIES	GRADE 32510	GRADE 35018
Tensile strength, psi	50,000	53,000
Yield point, psi	32,500	35,000
Elongation in 2 in., %	10.0	18.0

The yield point, defined as that load under which the specimen has an elongation in 2 in. of 0.01 in., may be determined by the drop of the beam of the testing machine or by the divider method.

Tension-Test Specimens[1]—Tension-test specimens shall be of the form and dimensions shown in Fig. 1. (Fig. 2 shows an alternate.) Specimens whose mean diameter at the smallest section is less than $1\frac{9}{32}$ in. will not be accepted for test.

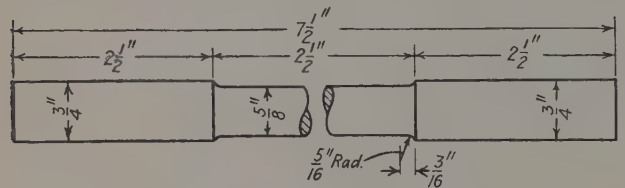


FIG. 1—MALLEABLE IRON TENSION-TEST SPECIMEN

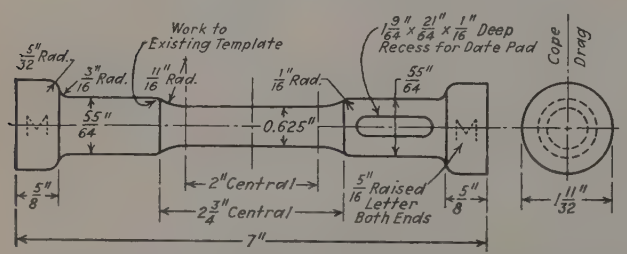


FIG. 2—ALTERNATE UNMACHINED TENSION-TEST SPECIMEN

Modifications may be made in the dimensions indicated above for those details of the specimen outside of the gage length as required by testing procedure and equipment.

A set of three tension-test specimens shall be cast from each melt, without chills, using heavy risers of sufficient height to secure sound bars. The specimens shall be suitably marked for identification with the melt. Each set of specimens so cast shall be placed in some one oven containing castings to be annealed.

Number of Tests—After annealing, three tension-test specimens shall be selected by the inspector as representing the castings in the oven from which these specimens are taken.

If the first specimen conforms to the specified requirements, or if, in the event of failure of the first specimen, the second and third specimens conform to the requirements, the castings in that oven shall be accepted, except that any casting may be rejected if its test lug shows that it has not been properly annealed. If either the second or third specimen fails to conform to the requirements, the entire contents of that oven shall be rejected. In case one of the retest specimens contains a flaw that results in the failure of the specimen to meet the specifications, at the discretion of the inspector additional test specimens from the same oven may be tested or test specimens may be cut from castings.

Reannealing—Any castings rejected for insufficient annealing may be reannealed once. The reannealed castings shall be inspected and if the remaining test lugs, or castings broken as specimens, show the castings to be thoroughly annealed, they shall be accepted; if not, they shall be finally rejected.

Special Tests—All castings, if of sufficient size, shall have cast thereon test lugs of a size proportional to the thickness of the casting, but not exceeding $\frac{5}{8}$ by $\frac{3}{4}$ in. in cross-section. On castings which are 24 in. or over in length, a test lug shall be cast near each end. These test lugs shall be attached to the casting at such a point that they will not interfere with the assembling of the castings, and may be broken off by the inspector.

If the purchaser or his representative so desires, a casting may be tested to destruction. Such a casting shall show good, tough malleable iron.

Workmanship—The castings shall conform substantially to the patterns or drawings furnished by the purchaser, and also to gages which may be specified in individual cases. The castings shall be made in a workmanlike manner. A variation of $\frac{1}{8}$ in per ft will be permitted.

Finish—The castings shall be free from injurious defects.

Marking—The manufacturer's identification mark and the pattern numbers assigned by the purchaser shall be cast on all castings of sufficient size, in such positions that they will not interfere with the service of the castings.

Inspection—The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

The manufacturer shall be required to keep a record of each melt from which castings are produced, showing tensile strength and elongation of test specimens cast from such melts. These records shall be available and shown to the inspector whenever required.

Rejection—Castings which show injurious defects subsequent to their acceptance at the manufacturer's works may be rejected and, if rejected, shall be replaced by the manufacturer.

[1] Tension-test specimens are not machined.

Pearlitic Malleable Iron Castings

SAE Standard

Report of Iron and Steel Technical Committee approved February 1948 and last revised January 1951. This SAE Standard conforms substantially to ASTM A 220–48 T.

Scope—These specifications cover pearlitic malleable iron castings for railroad, motor-vehicle, marine, agricultural-implement, and general machinery purposes, both for general use and for localized-hardening purposes.

Process—The iron shall be made by one of the following processes: air-furnace, open-hearth, electric-furnace, or any of the multiplex processes.

Physical Properties—The tension-test specimen shall conform to the minimum tensile-property requirements given in Table 1.

TABLE 1—*Physical-Property Requirements for Pearlitic Malleable Iron Castings*

PHYSICAL PROPERTIES[a]	GRADE				
	43010	48005	53004	60003	70002
Minimum tensile strength, psi	60,000	70,000	80,000	80,000	90,000
Minimum yield point or yield strength, psi	43,000	48,000	53,000	60,000	70,000
Minimum elongation in 2 in., %	10	5	4	3	2
Typical Bhn range	163–207	179–228	197–241	197–241	241–285

[a] It is recognized that higher tensile and higher yield strengths may be obtained from any one of the grades shown in the above table by the use of a conventional quench-and-temper treatment. This increase would be accompanied by a reduction in toughness and a likely increase in hardness.

The yield point or yield strength shall be determined in accordance with the Standard Methods of Tension Testing of Metallic Materials, ASTM E 8. For materials of low elongation, the determination by the drop of the beam or halt in the gage may be difficult or impossible.

Structure—When specified for localized-hardening processes, the selected grade designation shall be preceded by the letter L; as L48005, L60003. Such castings shall contain sufficient carbon in such combined form as to allow satisfactory induction, flame, or other localized hardening. A minimum of 197 Bhn is recommended. Free ferrite shall be as low as consistent with other properties.[1]

Test Specimens—At the option of the manufacturer and by agreement with the purchaser, machined test bars taken from any convenient coupon and machined according to Fig. 1 may be used. Unless otherwise agreed upon, cast tension-test specimens conforming to Fig. 2 or Fig. 3 shall be used.

The manufacturer shall cast three or more tension-test specimens from each heat in batch melting and at least every 4 hr of multiplex melting, without chills, using heavy risers of sufficient height to secure sound tension-test specimens. All specimens shall be suitably identified with the heat number in batch melting and with the pour period in multiplex melting.

All test specimens shall be heat-treated in regular production equipment as nearly as possible with castings which were made during the same operating heat.

[1] In the case of Grade 43010, however, strict adherence to the minimum elongation required in the specification may be waived in part in favor of the ability of the material to harden satisfactorily.

Number of Tests—(a) The manufacturer shall test at least one heat-treated tension-test specimen from each heat of batch melting and from each pour period of multiplex melting and shall record the results, except those of flawed bars, in permanent records. Such records covering the operating periods during which the purchaser's castings were produced should be available for examination by the purchaser's representative.

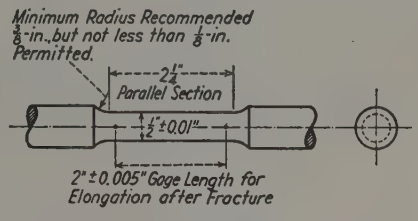

Minimum Radius Recommended
3/8-in., but not less than 1/8-in.
Permitted.
2 1/4"
Parallel Section
1/2" ±0.01"
2" ±0.005" Gage Length for
Elongation after Fracture
NOTE:-The gage length, parallel section, and fillets
shall be as shown, but the ends may be of any
shape to fit the holders of the testing machine
in such a way that the load shall be axial.

FIG. 1—MACHINED TENSION-TEST SPECIMEN

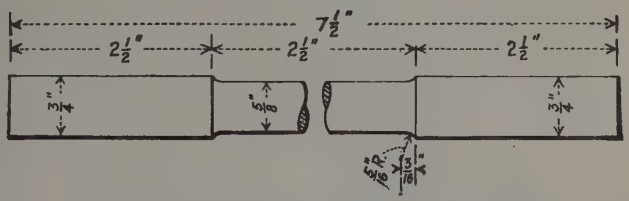


FIG. 2—UNMACHINED TENSION-TEST SPECIMEN

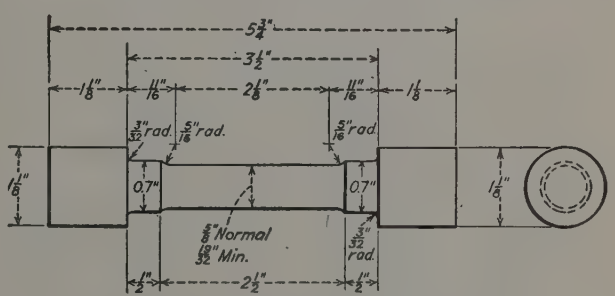


FIG. 3—ALTERNATIVE UNMACHINED TENSION-TEST SPECIMEN

(b) The purchaser's representative may select and test tension specimens representing the approximate operating period during which the purchaser's castings were produced. The test results of flawed tension-test specimens shall be discarded and duplicate specimens shall be tested.

(c) In lieu of conducting tests as provided in Paragraph (b), the purchaser's representative may elect to examine the manufacturer's test records for the approximate period during which the purchaser's castings were produced. He may further request certified copies of any representative tests which he may select.

(d) At the option of the purchaser or his representative, a

casting of each design ordered may be tested to destruction, or otherwise broken up, to determine the presence of any manufacturing condition which may be detrimental to the serviceability of the castings.

Reheat-Treatment—Any casting rejected may be reheat-treated. Test specimens shall be accepted if they fulfill the requirement of the specifications in accordance with the section on Physical Properties.

Permissible Variations in Dimensions—A variation of ⅛ in. per ft in any dimension will be permitted.

Workmanship—The castings shall be made in a workmanlike manner and shall conform substantially to the patterns or drawings furnished by the purchaser, and also to the gages which may be specified in individual cases.

Quality—All castings shall be substantially free from massive cementite (primary cementite), primary graphite, shrinks, cold shuts, cracks, injurious porosity, and other defects which would render the castings unsuitable for the purpose intended.

Marking—The identification mark of the manufacturer and the pattern numbers assigned by the purchaser shall be cast on all castings of sufficient size and in such positions that they will not interfere with the service of the castings.

Inspection—The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection—Material that shows injurious defects subsequent to its acceptance at the manufacturer's works may be rejected and, if rejected, shall be replaced by the manufacturer.

Automotive Steel Castings

SAE Recommended Practice

Report of Iron and Steel Technical Committee approved October 1946 and last revised August 1947.

[*This SAE Recommended Practice was formulated with the cooperation of the Steel Founders Society of America.*]

Scope—These specifications cover steel castings used in the automotive and allied industries.

General Data—In order to cover adequately the varying requirements encountered, the cast steels are classified into the following groups:

a—Plain carbon steels specified by chemical composition and minimum tensile properties (except for the carburizing grade, which is based on chemical composition only).

b—High-strength steels specified by minimum tensile properties, for miscellaneous uses where the requirements do not justify hardenability control.

c—High-strength steels specified by minimum tensile properties and hardenability requirements.

The chemical analysis used in the manufacture of high-strength steels shall be at the option of the foundry. Certain specific cases may arise where chemistry is a controlling factor in obtaining desired properties, such as wear resistance. Under these circumstances, chemistry may form part of this specification by specific agreement between the producer and purchaser in inquiry and purchase order.

Designation of Grades—All plain carbon steels specified by chemistry carry a prefix **00,** followed by the first two figures of the maximum carbon content.

All high-strength steels specified by tensile properties carry a prefix **0,** followed by the figures expressing the minimum tensile strength in thousands of pounds.

All high-strength steels specified by tensile properties and hardenability carry a prefix **0,** followed by the figures expressing the minimum tensile strength in thousands of pounds and a suffix **H** with a number and letter attached corresponding to the hardenability factor.

Grades of Steels and Requirements—The various grades of steels and their chemical and tensile requirements are shown in Tables 1 and 2. The hardenability factors are indicated in Fig. 1.

The fabrication of steel castings by fusion welding does not imply that no special precautions need be taken in welding any or all shapes of steel castings. Regardless of composition, the welding of any steel casting of intricate shape or of greatly varying cross-section may necessitate special welding technique not generally considered necessary for the welding of parts of reasonably symmetrical form.

When high-strength cast steels are to be used for fabrication

TABLE 1—*Grades of Steels and Requirements for Plain Carbon and Low-Alloy Cast Steel*

SAE Grade	APPROX. EQUIV. ASTM	APPROX. EQUIV. QQS-681-b	DESCRIPTION	CHEMICAL ANALYSIS,[a] % C	Mn	Si	Max P	Max S	RESIDUAL ALLOY LIMITATIONS	MIN TENSILE PROPERTIES[c] Tensile strength, psi	Yield point, psi	Elongation in 2 in., %	Reduction in area, %	Brinell hardness[d]	HEAT-TREATMENT[e]
0022	A-27 Rev.	—	Low-carbon cast steel suitable for carburizing.	0.12–0.22	0.50–0.90	0.60 max	0.05	0.06	Residual alloys shall be limited by maximum core hardness required subject to specific agreement between producer and purchaser in inquiry and order.	not required	not required	not required	not required	not required	A or N or N-T
0030	A-27 Rev.	1	General-purpose cast steel, welding grade.	0.30 max	0.70 max *Note a*	0.60 max	0.05	0.06	—[b]	65,000	35,000	24	35	131	A or N or N-T or Q-T
0050	—	3	Medium-high-carbon cast steel suitable for castings requiring high surface hardness.	0.40–0.50	0.50–0.90	0.20–0.60	0.05	0.06	To be specified by max hardenability values when residual alloy limitations are required subject to specific agreement between producer and purchaser in inquiry and order.	85,000 100,000	45,000 70,000	16 10	24 15	170 207	N or N-T Q-T
080	A-27 Rev.	3	Carbon or alloy cast steel (usually of lower C content than 0050).	not required	not required	—	0.05	0.06	—	80,000	40,000	18	30	163	A or N or N-T or Q-T
090	A-148 Rev.	4B2	Alloy cast steel.	not required	not required	—	0.05	0.06	—	90,000	60,000	20	40	187	N-T or N-Q-T

[a] For each reduction of 0.01% carbon below the maximum specified, an increase of 0.04% manganese above the maximum specified will be permitted to a maximum of 1% manganese.

[b] Residual alloys, the determination of which shall be a matter of agreement between the manufacturer and purchaser, shall not exceed the following limits in per cent: copper, 0.50; nickel, 0.50; chromium plus molybdenum, 0.25; tungsten, 0.10. Total content of these unspecified elements, max. 1.0%. For each 0.1% below this specified maximum alloy content of 1.0%, an increase of 0.02% chromium plus molybdenum content and 0.06% nickel and copper content above the specified maximum will be permitted. No change is recommended on the other chemistry or the carbon-manganese relationship.

[c] These values are to be obtained from coupons of 1 x 1¼ in. cross-section. Tempering temperatures for the castings are to be adjusted for the required Brinell hardness to compensate for variations of mass between casting and test bar.

[d] These values are applicable to casting sections not over 3 in. (Brinell hardness values are to be secured on castings only.)

[e] Abbreviations: A, anneal; N, normalize; N-T, normalize-temper; Q-T, quench-temper; N-Q-T, normalize-quench-temper.

TABLE 2—*High-Strength Steel Castings for Structural Purposes*

SAE Grade	APPROX. EQUIV.		DESCRIPTION	CHEMICAL ANALYSIS, %					MINIMUM TENSILE PROPERTIES[c]					HEAT-TREATMENT[b]
	ASTM	QQS-681-b		C	Mn	Si	Max P	Max S	Tensile strength, psi	Yield point, psi	Elongation in 2 in., %	Reduction in area, %	Brinell hardness[a]	
0105	A 148 Rev.	4C2	alloy cast steel	not required			0.05	0.06	105,000	85,000	17	35	217	N-Q-T
0120	A 148 Rev.	4C3	alloy cast steel	not required			0.05	0.06	120,000	100,000	14	30	248	N-Q-T
0150	A 148 Rev.	4C4	alloy cast steel	not required			0.05	0.06	150,000	125,000	9	22	311	N-Q-T
0175	—	—	alloy cast steel	not required			0.05	0.06	175,000	145,000	6	12	363	N-Q-T

[a] These values are applicable to casting sections not over 3 in.
[b] N-Q-T = Normalize-Quench-Temper.
[c] These values are to be obtained from coupons of 1 x 1¼ in. cross-section. Tempering temperatures for the castings are to be adjusted for the equivalent Brinell hardness.

by fusion welding, it is recommended that the carbon content be limited to 0.35% carbon, maximum.

Chemical Analysis—All steels based on chemistry shall conform to the ranges given for each grade in Table 1. The only chemical requirements for the balance of the steels in these specifications will be maximum phosphorus and sulfur contents as indicated.

Chemical or spectrochemical analysis of each melt of steel shall be made by the producer to determine the percentages of elements specified in Tables 1 and 2. Chemical analysis shall be made from drillings taken not less than ¼ in. beneath the surface of the test coupon made during the pouring of the heat, and shall conform to the specified requirements.

Check Analysis—When so desired, an analysis may also be made by the purchaser from a test specimen or casting representing each melt. The procedure outlined above shall be followed, and the chemical composition as determined shall conform with the requirements specified for the particular grade of steel in question.

In cases where differences of results occur between producer's and purchaser's laboratories, a party mutually agreeable may be authorized to act as referee.

Hardenability and Selection of Hardenability Factor—(These are subject to specific agreement between producer and purchaser in inquiry and purchase order.)

The degree of hardenability required depends largely upon the type of stresses to which the casting will be subjected in service and may vary from a deep-hardening steel (full quench hardness to the core) to a shallow-hardening steel.

To allow for these varying requirements, Fig. 1 has been set up to include the equivalent distance on the Jominy bar for full quench hardness throughout, as well as to a depth of ¼ and ⅛ of the critical section thickness. These values are indicated at the bottom of the table.

The relationship between these distances and the thickness of the casting, or the so-called "critical section thickness"—by which is here meant the thickness of the most highly stressed portion of the casting—is found at the top of the table.

The minimum carbon content (established by the foundry) will determine the minimum as-quenched Rockwell hardness deemed necessary to obtain optimum physical properties after tempering, as shown on the right of the table.

Hardenability Test—The hardenability of the steel used shall be determined on a standard 1-in. round Jominy specimen.[1]

From each heat used on a purchaser's castings, a representative specimen of the metal shall be poured. The specimens may be cast to size in metal molds or prepared from test coupons. Unless otherwise agreed to between the producer and the purchaser, the producer shall keep a record of the hardenability data representing all heats in question for a period of 3 months.

Heat-Treatment—The heat-treatment used in obtaining the required mechanical properties of the steels in Tables 1 and 2 shall be at the option of the producer unless otherwise specified in the inquiry and purchase order.

In the case of castings which are to be heat-treated by the purchaser, these castings shall be supplied in the annealed,[2] normalized, or normalized-and-tempered condition, and it is the responsibility of the producer to furnish castings, the test coupons of which will meet the tensile properties and hardenability specified under properly controlled conditions.

Temperature Control—Furnace temperature for heat-treating shall be effectively regulated by the use of pyrometers.

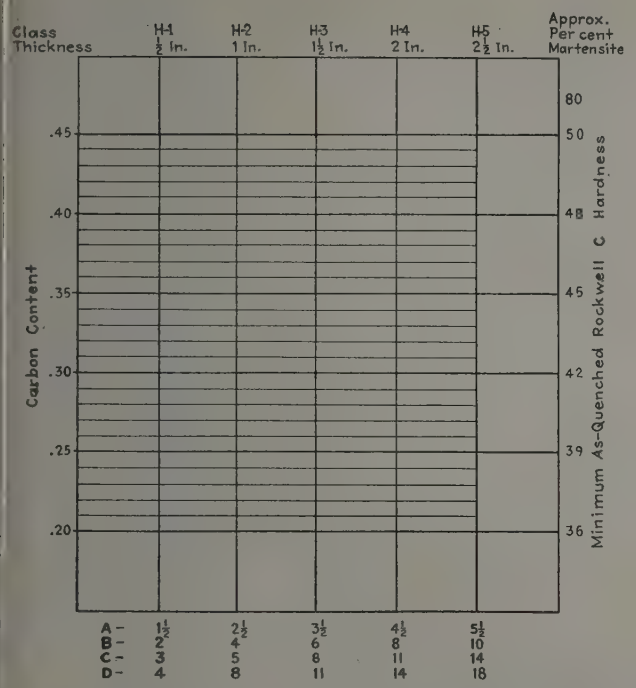
Tension Test—Tension-test specimens shall be prepared from test coupons. The test coupons shall be cast attached to the castings where practicable or in separate molds.

All test coupons from which specimens are to be prepared shall be given the same heat-treatment as the castings, subject to Footnote c of Tables 1 and 2. Tension-test specimens shall be machined to the dimensions shown for Fig. 3 of the SAE General Information Report on Tension-Test Specimens in this edition of SAE handbook or Fig. 3 of ASTM E 8–46.

For castings heat-treated by the producer, all testing and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified. In the case of castings to be heat-treated by the purchaser, the test bars shall be submitted to the purchaser in the form of a test coupon.

Tensile Properties—Steel used for castings shall conform to requirements as to tensile and other properties described in

[1] See the SAE Recommended Practice on Method of Determining Hardenability of Steels or ASTM A 255.
[2] See the SAE General Information Report of Definitions of Heat-Treating Terms.



A—For desired quench hardness to a depth of ⅛ of critical section thickness, agitated water quench
B—For desired quench hardness to a depth of ¼ of critical section thickness, agitated water quench
C—For desired quench hardness at center of critical section thickness, agitated water quench
D—For desired quench hardness at center of critical section thickness, agitated oil quench

FIG. 1—CRITICAL SECTION THICKNESS OF CASTING

The values in this table were obtained from plate sections. For rounds, refer to the SAE Recommended Practice on Method of Determining Hardenability of Steels.

These two examples indicate the application of Fig. 1:

1. A steel casting of 1-in. critical section thickness is required to meet a minimum of 105,000 psi tensile strength and subjected in service to tensional stresses.

As this casting will be loaded in tension, it is desirable to produce full quench hardness throughout the critical section thickness. In Fig. 1, the 1-in. thickness corresponds to class H-2 and requires a hardenability equivalent to a distance of 5/16 in. on the Jominy bar. The specification, therefore, would read "SAE 0105 H-2C" and would indicate to the foundry operating with a minimum carbon content of say, 0.30%, that a material of sufficient hardenability to produce a minimum of 42 Rockwell C at 5/16 in. on the Jominy bar is required; that is, J42 = 5.

2. In the case of another casting of similar cross-section and tensile requirements but subjected to torsional stresses, the purchaser may decide that full hardening throughout the section is not essential for satisfactory properties after tempering. In such a case, Fig. 1 permits specifying the hardenability required to produce full quench hardness to a depth of a quarter as well as one eighth of the critical section as indicated by letters B and A.

The distance on the Jominy bar for intricate castings requiring full hardening by oil quenching may be found under letter D.

Frequently, intricate designs are encountered, as in the case of a hollow casting where the outside and the inside may be subjected to different severity of quench, or a casting where the section size immediately adjacent to the critical section thickness may be larger or smaller, thereby affecting a decrease or increase in the cooling rate in the center of the critical section thickness. For such castings, the cooling rates or equivalent distance on the Jominy bar can not be established from Fig. 1 or calculated closely enough for guidance in selecting the proper steel. It becomes necessary in these cases, for the purchaser to determine the cooling rate at the critical section thickness for the particular casting.

This is best done by adopting the method described in SAE Transactions, Vol. 49, July, 1941, pp. 266-276, which method involves determination of hardnesses throughout the particular section in question after quenching from the hardening temperature and the substitution of cooling rates corresponding to the hardnesses, picked from a hardenability curve for the same steel previously used.

Tables 1 and 2. When specified in the inquiry and purchase order, the properties obtained shall be reported to the purchaser or his representative. For high-tensile steels where a definite yield point is not exhibited, the yield strength corresponding to a limiting permanent offset of 0.2% of the gage length of the specimen shall be used instead and reported as yield strength. This offset method is described in ASTM E 8.

Number of Tests—One tension test shall be made from each lot. The term "lot" shall be considered as all castings in a melt subjected to the same heat-treating procedure.

If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same lot.

If the percentage of elongation of any tension-test specimen is less than that specified in Tables 1 or 2 and any part of the fracture is more than ¾ in. from the center of the gage length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

If mutually satisfactory to the producer and purchaser, and after acceptance of consecutive melts used for making castings of any one grade, the producer and purchaser may establish reduced testing procedures. In all cases where hardenability forms part of the requirement, a Jominy test shall be conducted by the producer on a sample from each melt.

Retest—If the results of the tensile tests for any lot do not conform to the requirements specified, the manufacturer may reheat-treat such a lot. Retests of an additional specimen from the same lot shall be made and shall conform to the requirements specified above.

Hardness Test—In cases where hardness testing of castings is required, a rectangular boss approximately ¾ x 1½ in. and of sufficient thickness to eliminate decarburizing when ground off, and located on the casting in a manner permitting proper mounting in the Brinell machine, shall be indicated on the blueprints. That such a test is required shall be specified in the inquiry and purchase order after agreement between producer and purchaser.

The minimum Brinell hardness of castings shall conform to the requirements for the respective grades as shown in Tables 1 and 2.

The frequency of such Brinell inspection shall be established by agreement between producer and purchaser and shall be indicated in the inquiry and purchase order.

Optional Tests—(These are subject to specific agreement between the producer and purchaser in inquiry and purchase order.)

Load Testing—Load testing simulating service conditions may constitute the basis for acceptance of individual castings.

Test to Destruction—Tests to destruction may be used as a

basis of acceptance, and in this case the test shall show the material to be free from injurious defects and suitable for the purpose intended.

Non-Destructive Tests—*Radiographic Inspection*—When so specified in the inquiry and purchase order, and mutually agreed upon by the producer and purchaser, castings made to this specification may be subject to radiographic inspection.

Areas to be radiographed, number of pieces made from the same pattern which shall be radiographed,[3] and standards of acceptability shall be agreed upon by producer and purchaser.

Magnetic-Particle Inspection—When so specified in the inquiry and purchase order, and mutually agreed upon by producer and purchaser, castings made to this specification may be subject to magnetic-particle inspection.

Areas to be inspected, number of pieces made from the same pattern which shall be inspected, and standards of acceptability shall be agreed upon by producer and purchaser.

When so specified, the magnetic-particle inspection shall be in accordance with the SAE Recommended Practice for Magnetic-Particle Testing of Steels or ASTM A 272.

Repair of Defective Steel Castings—Repair of defective steel castings may be performed in (a) the foundry or (b) the machine shop.

(a) In the case where castings are to be repaired in the foundry, the following procedure is to be followed:

Minor defects that will not ultimately impair the strength, serviceability, or subsequent processing operations of the castings may be welded by an approved process such as is established by the American Welding Society for carbon and low-alloy steels. Defects shall be considered minor when the depth of the cavity prepared for welding is not greater than 20% of the actual wall thickness, but in no case greater than 1 in. Minor defects may be welded without securing the approval of the purchaser, whereas defects other than minor may be repaired with the consent of the purchaser, by welding with an approved process. All welds shall be given a suitable stress relief or heat-treatment.

[3] As long as there is no SAE radiographic standard, the Navy Bureau of Ships' Radiographic Standards for Steel Castings, dated July 1, 1942, are recommended as a basis of mutual agreement.

(b) For information relative to acceptable repair procedures applicable in the machine shop, refer to the SAE Special Publication SP-20, "Foundry Process Control Procedures (Ferrous)."

Workmanship—All castings shall be made in a workmanlike manner and shall conform substantially to the dimensions on drawings furnished by the purchaser before manufacture is started, or to the dimensions predicated by the pattern supplied by the purchaser if no drawings are provided.

Finish—The castings shall be free from injurious defects and shall be satisfactorily cleaned for their intended use when offered for inspection.

Marking—The manufacturer's identification mark, pattern number, and melt number shall appear on all castings except those of such small size as to make such marking impractical.

Inspection—The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed to all parts of the producer's works which concern the manufacture of the material ordered. The producer shall afford the inspector all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

If in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the inquiry and purchase order.

Rejection—Unless otherwise specified, any rejection based on tests made in accordance with the paragraph "Check Analysis" shall be reported to the producer within five working days from the receipt of samples by the purchaser.

Material which shows injurious defects subsequent to its acceptance at the producer's works will be rejected and the producer shall be notified.

Rehearing—Tested samples representing rejected material shall be held for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the producer may make claim for a rehearing within that time.

Chemical Compositions of SAE Corrosion- and Heat-Resistant Ferrous Castings

SAE Standard

From report of Iron and Steel Division approved June 1911 and last revised by Iron and Steel Technical Committee January 1950.

TABLE 1—*Corrosion-Resistant Alloy Steel Castings*

SAE Number	ASTM A 296 AND ACI[a]	CHEMICAL COMPOSITIONS, %								
		Max C	Max Mn	Max Si	Max P	Max S	Cr Range	Ni Range	Mo	Other elements
60303	CF–16F	0.16	1.50	2.00	0.17	0.04	18.0–21.0	9.0–12.0	1.5 max	Se, 0.20–0.35
60303A	CF–16F	0.16	1.50	2.00	0.04	0.20–0.40	18.0–21.0	9.0–12.0	0.40–0.80	—
60304	CF–8	0.08	1.50	2.00	0.04	0.04	18.0–21.0	8.0–11.0	—	—
60309	CH–20	0.20	1.50	2.00	0.04	0.04	22.0–26.0	12.0–15.0	—	—
60310	CK–20	0.20	1.50	2.00	0.04	0.04	23.0–27.0	19.0–22.0	—	—
60312	CE–30	0.30	1.50	2.00	0.04	0.04	26.0–30.0	8.0–11.0	—	—
60316	CF–8M	0.08	1.50	1.50	0.04	0.04	18.0–21.0	9.0–12.0	2.0–3.0	—
60347	CF–8C	0.08	1.50	2.00	0.04	0.04	18.0–21.0	9.0–12.0	—	(See Note c)
60410	CA–15	0.15	1.00	1.50	0.04	0.04	11.5–14.0	1 max	0.50 max	—
60420	CA–40[b]	0.20–0.40	1.00	1.50	0.04	0.04	11.5–14.0	1 max	0.50 max	—
60442	CB–30	0.30	1.00	1.00	0.04	0.04	18.0–22.0	2 max	—	—
60446	CC–50	0.50	1.00	1.00	0.04	0.04	26.0–30.0	4 max	—	—
60502	—	0.25	1.00	0.60	0.05	0.05	4.0–6.5	—	0.40–0.60	—

[a] ACI = Alloy Castings Institute.
[b] Not included in ASTM A 296—49 T.
[c] Minimum Cb = 8 × C. Maximum Cb = 1.0.

TABLE 2—*Heat-Resistant Alloy Steel Castings*

SAE Number	ASTM A 297 AND ACI[a]	CHEMICAL COMPOSITIONS, %								
		C	Max Mn	Max Si	Max P	Max S	Cr	Ni	Mo	Other elements
70308	HF	0.20–0.40	2.00	2.00	0.04	0.04	18.0–23.0	8.0–12.0	0.5 max	—
70309	HH	0.20–0.50	2.00	2.00	0.04	0.04	24.0–28.0	11.0–14.0	0.5 max	N, 0.2 max
70310	HK	0.20–0.60	2.00	3.00	0.04	0.04	24.0–28.0	18.0–22.0	0.5 max	—
70310A	HL[b]	0.20–0.60	2.00	3.00	0.04	0.04	28.0–32.0	18.0–22.0	0.5 max	—
70312	HE	0.20–0.50	2.00	2.00	0.04	0.04	26.0–30.0	8.0–11.0	0.5 max	—
70327	HD[b]	0.50 max	1.50	2.00	0.04	0.04	26.0–30.0	4.0–7.0	0.5 max	—
70330	HT	0.35–0.75	2.00	2.50	0.04	0.04	13.0–17.0	33.0–37.0	0.5 max	—
70331	HU	0.35–0.75	2.00	2.50	0.04	0.04	17.0–21.0	37.0–41.0	0.5 max	—
70334	HW	0.35–0.75	2.00	2.50	0.04	0.04	10.0–14.0	58.0–62.0	0.5 max	—
70335	HX	0.35–0.75	2.00	2.50	0.04	0.04	15.0–19.0	64.0–68.0	0.5 max	—
70446	HC	0.50 max	1.00	2.00	0.04	0.04	26.0–30.0	4 max	0.5 max	—
70502	—	0.25 max	1.00	0.75–1.50	0.05	0.05	4.5–6.5	—	0.40–0.60	—

[a] ACI = Alloy Castings Institute
[b] Not included in ASTM A 297—49 T.

Tool and Die Steels

SAE Recommended Practice

Report of Iron and Steel Technical Committee approved January 1949 and last revised January 1951.

[*The information and standards given in this section are considered to be tentative and are subject to modification to meet new developments or requirements. They are offered as a guide in the selection and use of tool steels.*]

Definition—Tool and die steels are defined as carbon or alloy steels, capable of being hardened and tempered, which are usually melted in electric furnaces and produced to meet special requirements for application in certain tools used by hand; and for tools and dies for use in mechanical fixtures for cutting, shaping, forming, and blanking of materials, either hot or cold; or for precision gages.

This definition is not intended to include that type of tonnage production open-hearth steel used in the manufacture of ordinary mechanics' hand tools, nor steel used in the manufacture of such products as hammers, picks, files, hollow drill steel, mining bits and cutters, large rolling mill rolls, and low-alloy medium-carbon forging die-blocks. These exceptions are stated as a matter of guidance only and are not inclusive.

Classification of Tool and Die Steels—To classify tool and die steels for engineers, metallurgists, tool designers, tool makers, tool-room supervisors, heat-treaters, and the like, the groups of tool and die steels are listed in Table 1.

The Selection of Tool and Die Steels[1]—Simplification of the problems connected with the selection of tool steels has long been an aim of both producers and consumers. This article is restricted to a discussion of the general principles involved in selection and will include a tabulation of the metallurgical characteristics of the principal tool-steel types as an aid in selection. A correlation of these metallurgical characteristics with the requirements of the tool in operation should form the basis of a sound approach to the selection of a steel for any application. (See Table 2.)

Practical experience indicates that in the majority of instances the choice is not limited to a single type of tool steel or even to a particular family of tool steels for a workable solution to an individual tooling problem. Because it is desirable to select the steel that will give the most economical overall performance, the tool life obtained with each steel under consideration should be judged by weighing such factors as expected productivity, ease of fabrication, and cost.

The majority of tool-steel applications can be divided into a small number of groups or types of operations: cutting, shearing, forming, drawing, extrusion, rolling, and battering. Cutting tools include drills, taps, broaches, hobs, lathe tools, and the like. Shearing tools include shears, blanking and trimming dies, punches, and such. Forming tools include draw dies, forging dies, cold heading dies, and die-casting dies. Battering tools include chisels and all forms of tools involving heavy shock. Many of these classifications can be further divided into cold-working and hot-working tools.

For each of these groups, certain metallurgical characteristics are of utmost importance. Most cutting tools require high hardness, high resistance to the softening effect of heat, and high wear resistance. Shearing tools require high wear resistance combined with fair toughness, and these characteristics must be properly balanced, depending on the tool design, thickness of stock being sheared, and temperature of the shearing operation. Forming tools must possess high wear resistance or high toughness and high strength, and many require maximum resistance to heat softening. In battering tools high toughness is most important.

Hardness, strength, toughness, wear resistance, and resistance to heat softening are, therefore, prime selective factors for tool-steel applications. Many other properties must be seriously considered in individual applications; these include permissible distortion in hardening, permissible surface decarburization, hardenability or depth of hardness desired, resistance to heat checking, machinability and grindability, as well as heat-treating requirements, including temperatures, atmospheres, and equipment.

Table 2 lists those properties which merit special consideration when selecting steels for any application, from the list shown. (For compositions of these steels, see Table 1.)

Table 3 is presented as an aid in the relative evaluation of those properties which must be considered for the proper heat-treatment of the steels.

Relation of Design to Heat-Treatment—The design bears, in many ways, upon the serviceability of the tool or machine part, and unsatisfactory performance may frequently be traced directly to faulty design. This discussion is concerned only with design as it affects the heat-treating operation and, through the heat-treatment, the serviceability of the finished part. It is the purpose of this discussion to bring about a better mutual understanding between the designer and the steel treater so that faulty design which may cause cracking or distorting during heat-treating can be avoided.

The fundamental principles of good design from a heat-treatment standpoint are quite simple. Heat-treated steel has a certain strength depending upon the analysis of the steel, the quality of the metal, and the heat-treatment which it has received. When subjected to a combination of forces beyond its ultimate strength, the steel cracks or fails. There are two types of force combining to break the steel, which are

1. The internal stress set up during fabrication and heat-treatment of the part.
2. The external force of service.

Sometimes the internal stresses alone exceed the strength of the metal, and the parts crack in hardening. Again, the internal stresses may equal 90% or more of the total strength, in which case failure will develop in service under relatively light loads. It therefore appears that the useful strength of a part decreases in proportion as the internal stresses increase.

Internal stresses arise from many causes, but the most serious by far are those developed by quenching, by reason of differential cooling. This differential cooling is largely a function of the size and shape of the piece being quenched; in other words, the design. Here, then, is the relation of design to heat-treatment, and the basic principle of successful design is to plan shapes which will allow the piece to cool as uniformly as possible during quenching.

(*Continued on next page.*)

[1] Condensed from the ASM Handbook, 1948 edition, pp. 658-659, with the permission of the American Society for Metals.

TABLE 1—*Classification and Approximate Compositions of Tool and Die Steels*

STEEL	C	Mn	Si	Cr	V	W	Mo	Co	Ni
Water-Hardening Tool Steels[a]									
0.80 Carbon	0.70–0.85	—[a]	—[a]	—[a]	—	—	—	—	—
0.90 Carbon	0.85–0.95	—[a]	—[a]	—[a]	—	—	—	—	—
1.00 Carbon	0.95–1.10	—[a]	—[a]	—[a]	—	—	—	—	—
1.20 Carbon	1.10–1.30	—[a]	—[a]	—[a]	—	—	—	—	—
0.90 Carbon-V	0.85–0.95	—[a]	—[a]	—[a]	0.15–0.35	—	—	—	—
1.00 Carbon-V	0.95–1.10	—[a]	—[a]	—[a]	0.15–0.35	—	—	—	—
1.00 Carbon-VV	0.95–1.10	—[a]	—[a]	—[a]	0.35–0.50	—	—	—	—
Oil-Hardening Tool Steels									
Low Manganese	0.90	1.20	0.25	0.50	0.20[c]	0.50	—	—	—
High Manganese	0.90	1.60	0.25	0.35[c]	0.20[c]	—	0.30[c]	—	—
High Carbon-High Chromium	2.15	0.35[b]	0.35	12.00	0.80[c]	0.75[c]	0.80[c]	—	0.50[c]
Chromium	1.00	0.35	0.25	1.40	—	—	0.40	—	—
Molybdenum Graphitic	1.45	0.75	1.00	—	—	—	0.25	—	—
Nickel-Chromium	0.75	0.70[b]	0.25	0.85[b]	0.25[c]	—	0.50[c]	—	1.50[b]
Air-Hardening Tool Steels									
High Carbon-High Chromium	1.50	0.40	0.40	12.00	0.80[c]	—	0.90	0.60[c]	—
5% Chromium Air Hard	1.00	0.60	0.25	5.25	0.40[c]	—	1.10	—	—
High Carbon-High Chromium-Cobalt	1.50	0.40	0.40	12.00	0.80[c]	—	0.90	3.10	—
Shock-Resisting Tool Steels									
Chromium-Tungsten	0.50	0.25	0.35[b]	1.40	0.20	2.25	0.40[c]	—	—
Silicon-Molybdenum	0.50	0.40	1.00	—	0.25[c]	—	0.50	—	—
Silicon-Manganese	0.55	0.80	2.00	0.30[c]	0.25[c]	—	0.40[c]	—	—
Hot-Work Tool Steels									
Chromium-Molybdenum-Tungsten	0.35	0.30	1.00	5.00	0.25[c]	1.25	1.50	—	—
Chromium-Molybdenum-V	0.35	0.30	1.00	5.00	0.40	—	1.50	—	—
Chromium-Molybdenum-VV	0.35	0.30	1.00	5.00	0.90	—	1.50	—	—
Tungsten	0.32	0.30	0.20	3.25	0.40	9.00	—	—	—
High-Speed Tool Steels									
Tungsten 18-4-1	0.70	0.30	0.30	4.10	1.10	18.00	—	—	—
Tungsten 18-4-2	0.80	0.30	0.30	4.10	2.10	18.50	0.80	—	—
Tungsten 18-4-3	1.05	0.30	0.30	4.10	3.25	18.50	0.70	—	—
Cobalt-Tungsten 14-4-2-5	0.80	0.30	0.30	4.10	2.00	14.00	0.80	5.00	—
Cobalt-Tungsten 18-4-1-5	0.75	0.30	0.30	4.10	1.00	18.00	0.80	5.00	—
Cobalt-Tungsten 18-4-2-8	0.80	0.30	0.30	4.10	1.75	18.50	0.80	8.00	—
Cobalt-Tungsten 18-4-2-12	0.80	0.30	0.30	4.10	1.75	20.00	0.80	12.00	—
Molybdenum 8-2-1	0.80	0.30	0.30	4.00	1.15	1.50	8.50	—	—
Molybdenum-Tungsten 6-6-2	0.83	0.30	0.30	4.10	1.90	6.25	5.00	—	—
Molybdenum-Tungsten 6-6-3	1.15	0.30	0.30	4.10	3.25	5.75	5.25	—	—
Molybdenum-Tungsten 6-6-4	1.30	0.30	0.30	4.25	4.25	5.75	5.25	—	—
Cobalt-Molybdenum-Tungsten 6-6-2-8	0.85	0.30	0.30	4.10	2.00	6.00	5.00	8.00	—

[a] Water-hardening steels listed herein are usually available in four grades or qualities as follows:
Special (Grade 1)—The highest quality water-hardening carbon tool steel, controlled for hardenability, chemistry held to closest limits, and subject to most rigid tests to insure maximum uniformity in performance.
Extra (Grade 2)—A high quality water-hardening carbon tool steel, controlled for hardenability, subject to tests to insure good service for general application.
Standard (Grade 3)—A good quality water-hardening carbon tool steel, not controlled for hardenability, recommended for application where some latitude with respect to uniformity is permissible.
Commercial (Grade 4)—A commercial quality water-hardening carbon tool steel, not controlled for hardenability, not subject to special tests.
On special and extra grades, limits on manganese, silicon, and chromium are not generally required in lieu of the following Shepherd hardenability limits:

	0.70–0.85 C and 0.85–0.95 C		0.95–1.10 C and 1.10–1.30 C	
	Hardenability, 64ths In. Penetration	*Fracture Grain Size*	*Hardenability, 64ths In. Penetration*	*Fracture Grain Size*
Shallow	10 max	8 min	8 max	9 min
Regular	9 to 13	8 min	7 to 11	9 min
Deep	12 min	8 min	10 to 16	8 min

On standard and commercial grades, the following limits on composition are generally required:

	Mn	Si	Cr
Standard	0.35 max	0.35 max	0.15 max
Commercial	0.35 max	0.35 max	0.20 max

[b] Total of manganese, silicon, and chromium not to exceed 0.75%.
[b] May be present in percentages other than shown.
[c] Optional element. Steels have found satisfactory application either with or without the element present.

(*Continued on next page.*)

TABLE 2—*Comparison of Tool Steels Listed in Table 1 on Basis of Properties Affecting Selection*

STEEL	NONDEFORMING PROPERTIES	SAFETY IN HARDENING	DEPTH OF HARDENING	TOUGHNESS	RESISTANCE TO SOFTENING EFFECT OF HEAT	WEAR RESISTANCE	MACHINABILITY
Water-Hardening Tool Steels							
0.80 Carbon	Poor	Fair	Shallow	Good[a]	Poor	Fair	Best
0.90 Carbon	Poor	Fair	Shallow	Good[a]	Poor	Fair	Best
1.00 Carbon	Poor	Fair	Shallow	Good[a]	Poor	Good	Best
1.20 Carbon	Poor	Fair	Shallow	Good[a]	Poor	Good	Best
0.90 Carbon-V	Poor	Fair	Shallow	Good	Poor	Fair	Best
1.00 Carbon-V	Poor	Fair	Shallow	Good	Poor	Good	Best
1.00 Carbon-VV	Poor	Fair	Shallow	Good	Poor	Good	Best
Oil-Hardening Tool Steels							
Low Manganese	Good	Good	Deep	Fair	Poor	Good	Good
High Manganese	Good	Good	Deep	Fair	Poor	Good	Good
High Carbon-High Chromium	Good	Good	Through	Poor	Fair	Best	Poor
Chromium	Fair	Good	Deep	Fair	Poor	Good	Fair
Molybdenum Graphitic	Fair	Good	Deep	Fair	Poor	Good	Best
Nickel-Chromium	Fair	Good	Deep	Fair	Poor	Fair	Fair
Air-Hardening Tool Steels							
High Carbon-High Chromium	Best	Best	Through	Fair	Fair	Best	Poor
5% Chromium Air Hard	Best	Best	Through	Fair	Fair	Good	Fair
High Carbon-High Chromium-Cobalt	Best	Best	Through	Fair	Fair	Best	Poor
Shock-Resisting Tool Steels							
Chromium-Tungsten	Fair	Good	Deep	Good	Fair	Fair	Fair
Silicon-Molybdenum	W Poor[b] O Fair[b]	W Poor[b] O Good[b]	Deep	Best	Fair	Fair	Good
Silicon-Manganese	W Poor[b] O Fair[b]	W Poor[b] O Good[b]	Deep	Best	Fair	Fair	Fair
Hot-Work Steels							
Chromium-Molybdenum-Tungsten	Good	Good	Through	Good	Good	Fair	Fair
Chromium-Molybdenum-V	Good	Good	Through	Good	Good	Fair	Fair
Chromium Molybdenum-VV	Good	Good	Through	Good	Good	Fair	Fair
Tungsten	Good	Good	Through	Good	Good	Fair	Fair
High-Speed Tool Steels							
Tungsten 18-4-1	Good	Good	Through	Poor	Good	Good	Fair
Tungsten 18-4-2	Good	Good	Through	Poor	Good	Good	Fair
Tungsten 18-4-3	Good	Good	Through	Poor	Good	Best	Fair
Cobalt-Tungsten 14-4-2-5	Good	Fair	Through	Poor	Best	Good	Fair
Cobalt-Tungsten 18-4-1-5	Good	Fair	Through	Poor	Best	Good	Fair
Cobalt-Tungsten 18-4-2-8	Good	Fair	Through	Poor	Best	Good	Fair
Cobalt-Tungsten 18-4-2-12	Good	Fair	Through	Poor	Best	Good	Fair
Molybdenum 8-2-1	Good	Fair	Through	Poor	Good	Good	Fair
Molybdenum-Tungsten 6-6-2	Good	Fair	Through	Poor	Good	Good	Fair
Molybdenum-Tungsten 6-6-3	Good	Fair	Through	Poor	Good	Best	Fair
Molybdenum-Tungsten 6-6-4	Good	Fair	Through	Poor	Good	Best	Fair
Cobalt-Molybdenum-Tungsten 6-6-2-8	Good	Fair	Through	Poor	Best	Good	Fair

[a] Toughness decreases somewhat with increasing depth of hardening.
[b] "W" as shown here indicates water quench. "O" as shown here indicates oil quench.

Some shapes are almost impossible to harden because of the abruptness in the change of sections, but a certain latitude in the design is recognized when using an oil-hardening or air-hardening steel.

Errors in design reach further than merely affecting the internal stresses of hardening. A sharp angle serves to concentrate greatly the stresses of service. The design of the part may be entirely responsible for concentrating the service stresses at a point already weakened by internal stresses produced during hardening.

Reducing all the foregoing to a single statement, a part is prop-

TABLE 3—*Approximate Comparison of Tool and Die Steels on Basis of Some Heat-Treating Characteristics*

STEEL	QUENCH MEDIUM	PREHEAT TEMPERATURE, F	HARDENING TEMPERATURE RANGE,[a] F	HARDNESS AFTER QUENCHING, ROCKWELL C	TEMPERING TEMPERATURE RANGE,[a] F	HARDNESS AFTER TEMPERING, ROCKWELL C	DECARBURIZATION (PREVENTION OF DURING HEAT-TREATMENT)
Water-Hardening Tool Steels							
0.80 Carbon	Water	—[b]	1420–1450	65–67	350–525	65–56	—[c]
0.90 Carbon	Water	—[b]	1420–1450	65–67	350–525	65–56	—[c]
1.00 Carbon	Water	—[b]	1420–1450	65–67	350–525	65–56	—[c]
1.20 Carbon	Water	—[b]	1420–1500	65–67	350–525	65–56	—[c]
0.90 Carbon-V	Water	—[b]	1420–1500	65–67	350–525	65–56	—[c]
1.00 Carbon-V	Water	—[b]	1420–1500	65–67	350–525	65–56	—[c]
1.00 Carbon-VV	Water	—[b]	1420–1500	65–67	350–525	65–56	—[c]
Oil-Hardening Tool Steels							
Low Manganese	Oil	—[b]	1450–1500	63–65	300–800	62–50	—[c]
High Manganese	Oil	—[b]	1420–1450	63–65	375–500	62–57	—[c]
High Carbon-High Chromium	Oil	1200–1300	1750–1800	62–64	400–700	62–58	—[d]
Chromium	Oil	—[b]	1525–1550	63–65	350–500	62–60	—[c]
Molybdenum Graphitic	Oil	—[b]	1450–1500	63–65	300–800	63–50	—[c]
Nickel-Chromium	Oil	—[b]	1500–1600	62–64	400–800	62–48	—[c]
Air-Hardening Tool Steels							
High Carbon-High Chromium	Air	1200–1300	1800–1875	61–63	400–700	60–58	—[d]
5% Chromium Air Hard	Air	1200–1300	1725–1775	61–63	400–700	60–57	—[d]
High Carbon-High Chromium-Cobalt	Air	1200–1300	1800–1875	60–62	400–700	59–57	—[d]
Shock-Resisting Tool Steels							
Chromium-Tungsten	Oil	1200–1300	1650–1800	57–59	300–1000	57–45	—[d]
Silicon-Molybdenum	Water	—[b]	1550–1575	60–62	300–500	60–54	—[c]
	Oil	—[b]	1600–1625	58–60	300–500	58–54	—[c]
Silicon-Manganese	Water	—[b]	1550–1600	60–62	300–650	60–54	—[c]
	Oil	—[b]	1600–1675	58–60	300–650	58–54	—[c]
Hot-Work Steels							
Chromium-Molybdenum-Tungsten	Oil, Air	1450–1500	1800–1900	53–55	1000–1100	51–43	—[d]
Chromium-Molybdenum-V	Air	1450–1500	1825–1875	53–55	1000–1100	51–43	—[d]
Chromium-Molybdenum-VV	Air	1400–1450	1825–1875	53–55	1000–1100	51–43	—[d]
Tungsten	Oil, Air	1500–1550	2100–2150	50–52	950–1150	50–47	—[d]
High-Speed Tool Steels							
Tungsten 18-4-1	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65–63	—[d]
Tungsten 18-4-2	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65–63	—[d]
Tungsten 18-4-3	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65–63	—[d]
Cobalt-Tungsten 14-4-2-5	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65–63	—[d]
Cobalt-Tungsten 18-4-1-5	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65–63	—[d]
Cobalt-Tungsten 18-4-2-8	Oil, Air, Salt	1500–1550	2300–2400	63–65	1050–1100	65–63	—[d]
Cobalt-Tungsten 18-4-2-12	Oil, Air, Salt	1500–1550	2300–2400	63–65	1050–1100	65–63	—[d]
Molybdenum 8-2-1	Oil, Air, Salt	1400–1500	2150–2250	63–65	1025–1050	65–63	—[d]
Molybdenum-Tungsten 6-6-2	Oil, Air, Salt	1450–1500	2175–2250	63–65	1025–1075	65–63	—[d]
Molybdenum-Tungsten 6-6-3	Oil, Air, Salt	1450–1500	2150–2225	63–65	1025–1075	65–63	—[d]
Molybdenum-Tungsten 6-6-4	Oil, Air, Salt	1450–1500	2150–2225	63–65	1025–1075	65–63	—[d]
Cobalt-Molybdenum-Tungsten 6-6-2-8	Oil, Air, Salt	1450–1500	2225–2275	63–65	1025–1100	65–63	—[d]

[a] The purpose of these columns is to show the usual ranges of temperature employed in hardening and tempering and is not to be used as a specification.
[b] For large tools and tools having intricate sections, preheating at 1050 F to 1200 F is recommended.
[c] Use moderately oxidizing atmosphere in furnace or a suitable neutral salt bath.
[d] Use protective pack from which volatile matter has been removed, carefully balanced neutral salt bath, or atmosphere controlled furnaces. In the latter case, the furnace atmosphere should be in equilibrium with the carbon content of the steel being treated. Furnace atmosphere dew point is considered a reliable method for measuring and controlling this equilibrium.

(*Continued on next page.*)

erly designed from the standpoint of heat-treatment when the entire piece may be heated and cooled at approximately the same rate during the heat-treating operation. Perfection in this regard is unattainable because, even in a sphere, the surface cools more rapidly than the interior. The designer should, however, attempt to so shape his parts that they will heat and cool as uniformly as possible. The greater the temperature difference between any two points on a given part during quenching and the closer these two points are together, the greater will be the internal stresses and, therefore, the poorer the design.

The principles described in this article are illustrated in Fig. 1.

(*Text continued after Table 4.*)

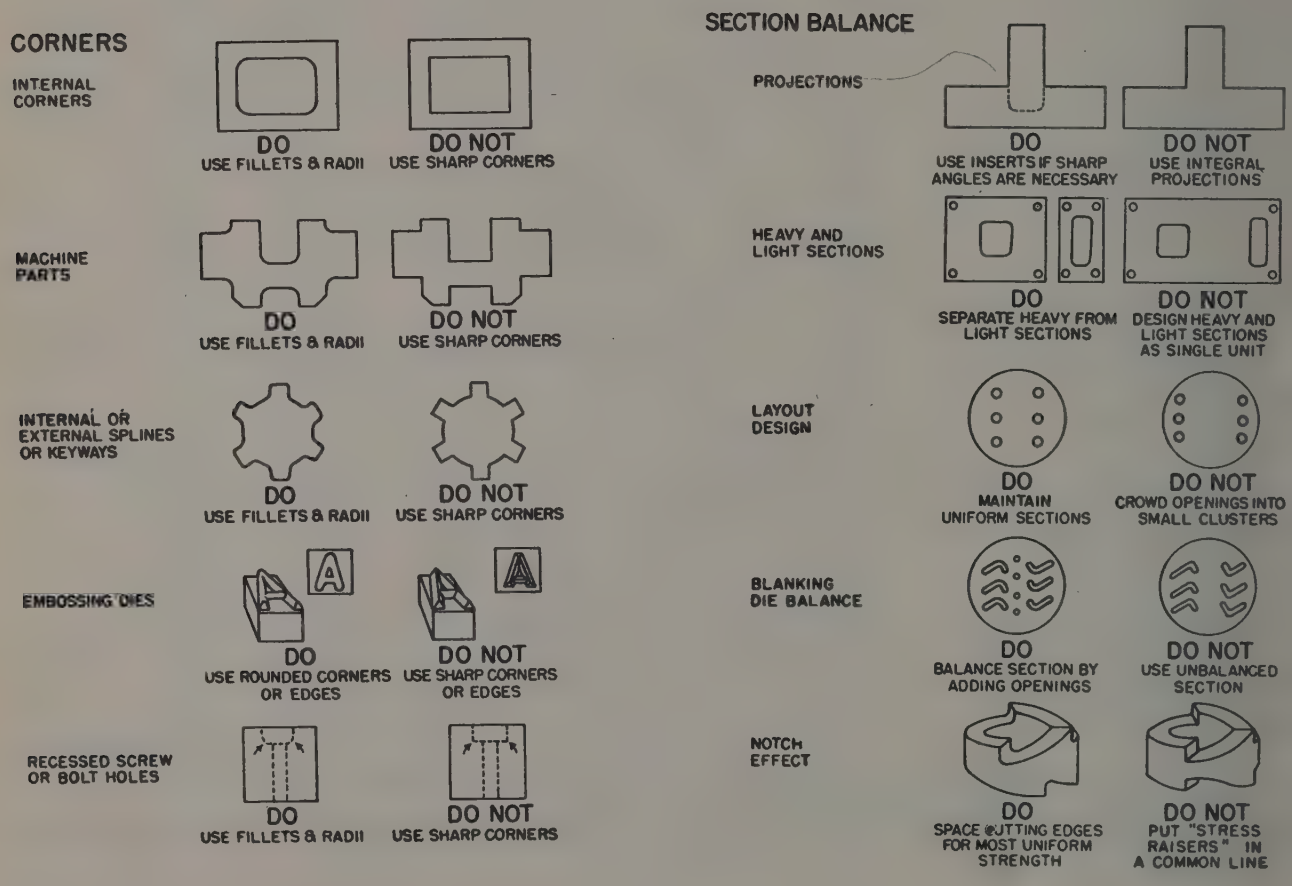


FIG. 1—TOOL AND DIE DESIGN TIPS (TO REDUCE BREAKAGE IN HEAT-TREATING)

TABLE 4—*Forging, Normalizing, and Annealing Treatments of Tool and Die Steels*

STEEL[a]	FORGING[b]			NORMALIZING[c]		ANNEALING[d]			
	Heat slowly to	Start forging at	Do not forge below	Heat slowly to	Hold at	Temperature	Maximum rate of cooling	Approximate Brinell hardness	Approximate Rockwell B
							F/hr		
Water-Hardening Tool Steels									
0.80 Carbon	1450	1800–1950	1500	1450	1500	1400–1450	75	159–202	84–94
0.90 Carbon	1450	1800–1950	1500	1450	1500	1375–1425	75	159–202	84–94
1.00 Carbon	1450	1800–1900	1500	1450	1550	1400–1450	75	159–202	84–94
1.20 Carbon	1450	1800–1900	1500	1450	1625	1400–1450	75	159–202	84–94
0.90 Carbon-V	1450	1800–1950	1500	1450	1500	1375–1425	75	159–202	84–94
1.00 Carbon-V	1450	1800–1900	1500	1450	1550	1400–1450	75	159–202	84–94
1.00 Carbon-VV	1450	1800–1900	1500	1450	1550	1400–1450	75	159–202	84–94
Oil-Hardening Tool Steels									
Low Manganese	1500	1750–1900	1550	1500	1600	1425–1475	50	183–212	90–96
High Manganese	1500	1750–1900	1550	1500	1550	1375–1425	50	183–212	90–96
High Carbon-High Chromium	1650	1850–2000	1650	Do not normalize		1600–1650	50	212–255	96–102
Chromium	1500	1800–2000	1550	1550	1650	1450–1500	50	174–212	88–96
Molybdenum Graphitic	1500	1750–1900	1500	1500	1625	1425–1475	20	183–217	90–96
Nickel-Chromium	1500	1800–2000	1600	1550	1650	1400–1450	50	183–212	90–96
Air-Hardening Tool Steels									
High Carbon-High Chromium	1650	1850–2000	1650	Do not normalize		1600–1650	40	207–255	95–102
5% Chromium Air Hard	1600	1850–2000	1650	Do not normalize		1550–1600	40	202–229	94–98
High Carbon-High Chromium-Cobalt	1600	1850–2000	1650	Do not normalize		1600–1650	40	207–255	95–102
Shock-Resisting Tool Steels									
Chromium-Tungsten	1500	1800–2000	1600	Do not normalize		1450–1500	50	192–235	92–99
Silicon-Molybdenum	1500	1900–2100	1600	1500	1650	1400–1450	50	192–229	92–98
Silicon-Manganese	1500	1900–2050	1600	1500	1600	1400–1450	50	192–229	92–98
Hot-Work Tool Steels									
Chromium-Molybdenum-Tungsten	1650	1950–2100	1650	Do not normalize		1600–1650	50	192–229	92–98
Chromium-Molybdenum-V	1650	1950–2100	1650	Do not normalize		1550–1600	50	192–229	92–98
Chromium-Molybdenum-VV	1650	1950–2100	1650	Do not normalize		1550–1600	50	192–229	92–98
Tungsten	1600	2000–2150	1650	Do not normalize		1600–1650	50	202–235	94–99
High-Speed Tool Steels									
Tungsten 18-4-1	1600	1950–2100	1750	Do not normalize		1600–1650	50	217–255	96–102
Tungsten 18-4-2	1600	2000–2150	1750	Do not normalize		1600–1650	50	223–255	97–102
Tungsten 18-4-3	1600	2000–2150	1750	Do not normalize		1600–1650	50	229–255	98–102
Cobalt-Tungsten 14-4-2-5	1600	2000–2150	1750	Do not normalize		1600–1650	50	229–255	98–102
Cobalt-Tungsten 18-4-1-5	1600	2000–2150	1750	Do not normalize		1600–1650	50	229–255	98–102
Cobalt-Tungsten 18-4-2-8	1600	2000–2150	1800	Do not normalize		1600–1650	50	248–293	102–106
Cobalt-Tungsten 18-4-2-12	1600	2000–2150	1800	Do not normalize		1625–1675	50	248–293	102–106
Molybdenum 8-2-1	1500	1900–2050	1700	Do not normalize		1525–1600	50	207–248	95–102
Molybdenum-Tungsten 6-6-2	1500	1950–2100	1700	Do not normalize		1550–1625	50	217–248	96–102
Molybdenum-Tungsten 6-6-3	1500	2000–2150	1700	Do not normalize		1550–1625	50	223–255	97–102
Molybdenum-Tungsten 6-6-4	1500	2000–2150	1700	Do not normalize		1550–1625	50	229–255	98–102
Cobalt-Molybdenum-Tungsten 6-6-2-8	1500	1950–2100	1750	Do not normalize		1550–1625	50	235–277	99–104

[a] These tool and die steels are the same as those listed in Table 1 of this SAE Recommended Practice.

[b] The temperature at which to start forging is given as a range, the higher side of which should be used for large sections and heavy or rapid reductions and the lower side for smaller sections and lighter reductions. As the alloy content of the steel increases, the time of soaking at forging temperature increases proportionately. Likewise, as the alloy content increases, it becomes more necessary to cool slowly from the forging temperature. With very high-alloy steels, such as high-speed steels or air-hardening steels, this slow cooling is imperative in order to prevent cracking and to leave the steel in a semi-soft condition. Either furnace cooling or burying in an insulating medium, such as lime, mica, or silocel, is satisfactory.

[c] The length of time the steel is held, after being uniformly heated through at the normalizing temperature, varies from about 15 min for a small section to about 1 hr for large sizes. Cooling from the normalizing temperature is done in still air. The purpose of normalizing after forging is to refine the grain structure and to produce a uniform structure throughout the forging. Normalizing should not be confused with low-temperature (about 1200 F) annealing used for the relief of residual stresses resulting from heavy machining, bending, and forming.

The annealing temperature is given as a range, the upper limit of which should be used for large sections and the lower limit for smaller sections. The length of time the steel is held after being uniformly heated through at the annealing temperature varies from about 1 hr for light sections and small furnace charges of carbon or low-alloy steel, to about 4 hr for heavy sections and large furnace charges of high-alloy steel.

For information on the forging and heat-treating of tool steel, see ASM Handbook, 1948 edition, pp. 653–655.

Allowance for Machining of Tool-Steel Bars[2]—Tool and die steels should be ordered oversize with sufficient material to be removed from all surfaces by machining or grinding to allow for:

(a) Surface decarburization.

(b) Surface defects such as slivers, seams, laps, scale marks, and the like.

(c) Undersize tolerance as given in Tables 6, 7, 8, and 9.

Table 5 lists the minimum allowance per side over finish size for machining or grinding rounds, squares, hexagons, and octagons.

Polished or ground tool-steel quality round drill rod is free from decarburization or any surface defects requiring surface removal.

[2] In cooperation with AISI.

TABLE 5—*Minimum Allowance*

SIZE, IN.	MINIMUM ALLOWANCE ON ONE SIDE, IN.				
	Hot rolled	Hammered	Rough turned	Cold drawn	Rough ground
To ½ incl	0.020	—	—	0.020	0.005
Over ½ to 1 incl	0.040	—	—	0.040	0.010
Over 1 to 2 incl	0.060	0.090	—	0.060	0.015
Over 2 to 3 incl	0.080	0.120	0.025	0.080	0.020
Over 3 to 4 incl	0.100	0.150	0.030	0.100	0.025
Over 4 to 6 incl	0.187	0.190	0.045	—	—
Over 6 to 8 incl	0.250	0.250	0.060	—	—
Over 8	—	0.250	0.090	—	—

TABLE 6a—*Tool-Steel Size Tolerances for Hot-Rolled Bars (Rounds, Squares, Octagons, and Hexagons)*

SPECIFIED SIZES, IN.		PERMISSIBLE VARIATIONS FROM SIZE, IN.		
Over	To and including	Under	Over	Out of section
—	½	0.005	0.012	0.010
½	1	0.010	0.016	0.013
1	1½	0.012	0.020	0.018
1½	2	0.015	0.025	0.021
2	2½	0.020	0.030	0.025
2½	3	0.020	0.040	0.030
3	4	0.025	0.050	0.035
4	5	0.025	0.060	0.035

TABLE 6b—*Tool-Steel Size Tolerances for Hot-Rolled Flats*

SPECIFIED WIDTHS, IN.		PERMISSIBLE VARIATIONS, IN.									
		Width		Variation from thickness for thickness given, in.							
				To ¼		Over ¼ to ½		Over ½ to 1		Over 1 to 2	
Over	To and including	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over
—	1	1/64	1/32	0.006	0.010	0.008	0.012	0.010	0.016	0.020	0.020
1	2	1/32	3/64	0.006	0.014	0.008	0.016	0.010	0.020	0.020	0.024
2	3	1/32	3/64	0.006	0.018	0.008	0.020	0.010	0.024	0.020	0.027
3	4	3/64	1/16	0.008	0.020	0.010	0.022	0.013	0.024	0.024	0.030
4	5	3/64	1/16	0.010	0.020	0.012	0.024	0.015	0.030	0.027	0.035
5	6	1/16	3/32	0.012	0.020	0.014	0.030	0.018	0.030	0.030	0.035

TABLE 7a—*Tool-Steel Size Tolerances for Hammered Flats*

SPECIFIED WIDTH, IN.		PERIMISSIBLE VARIATIONS, IN.											
		Width		Variation from thickness for thicknesses given, in.									
				To 1		Over 1 to 3		Over 3 to 5		Over 5 to 7		Over 7	
Over	To and including	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over
1	3	0.031	0.078	0.016	0.031	0.031	0.078	—	—	—	—	—	—
3	5	0.062	0.125	0.031	0.062	0.047	0.094	0.062	0.125	—	—	—	—
5	7	0.125	0.187	0.047	0.094	0.062	0.125	0.078	0.156	0.125	0.187	—	—
7	—	0.187	0.312	0.062	0.125	0.078	0.156	0.094	0.187	0.156	0.219	0.187	0.312

(*Continued on next page.*)

TABLE 7b—*Tool-Steel Size Tolerances for Hammered Bars (Rounds, Squares, Octagons, and Hexagons)*

SPECIFIED SIZES, IN.	PERMISSIBLE VARIATIONS FROM SIZE, IN.	
	Under	Over
Over 1 to 2 incl	0.030	0.060
Over 2 to 3 incl	0.030	0.080
Over 3 to 5 incl	0.060	0.125
Over 5 to 7 incl	0.125	0.187
Over 7	0.187	0.312

TABLE 8—*Tool-Steel Size Tolerances for Cold-Drawn Bars and Flats*

ROUNDS, OCTAGONS, QUARTER OCTAGONS, HEXAGONS		SQUARES, FLATS	
Specified sizes, in.	Permissible variation from size, in., plus or minus	Specified sizes, in.	Permissible variation from size, in., plus or minus
2¾ to 1	0.003	Over 1½	0.004
31/32 to ½	0.0025	1½ to ¾	0.003
15/32 to ¼	0.002	¾ to ¼	0.002

TABLE 9—*Tool-Steel Size Tolerances for Centerless Ground Bars, Rounds*

SPECIFIED SIZES, IN.	PERMISSIBLE VARIATIONS FROM SIZE, IN., PLUS OR MINUS
2¾ to ½	0.002
15/32 to ¼	0.0015

TABLE 10a—*Tool-Steel Size Tolerances for Drill-Rod Rounds (Polished or Ground)*

SPECIFIED SIZES, IN.	PERMISSIBLE VARIATIONS FROM SIZE, IN.	
	Standard manufacturing tolerance, plus or minus	Special manufacturing tolerance, plus or minus
1.500 to 0.500	0.001	0.0005
0.499 to 0.125	0.0005	0.00025
0.124 and smaller	0.0003	0.0002

TABLE 10b—*Tool-Steel Size Tolerances for Drill-Rod Squares Flats, Hexagons, and Octagons (Cold Drawn)*

SPECIFIED SIZES, IN.	PERMISSIBLE VARIATIONS FROM SIZE, IN., PLUS OR MINUS
1 to ¾	0.0015
11/16 to ¼	0.001
Smaller than ¼	0.0005

Standards for Austenitic Grain Size of Tool and Die Steels—It is recommended that the following methods be used for the determination of austenitic grain size of hardened tool steels:

Carbon Tool Steels—the Shepherd penetration-fracture test.

High-Speed Tool Steels—the Snyder-Graff intercept method.

The Shepherd Penetration-Fracture Test—This test is used to determine hardenability and fracture grain size on tool and die steels. It is generally applied to carbon tool steels. To perform the test, a sample is machined to ¾ in. diameter x 3 in. long and pretreated by holding at 1600 F for 30 min and quenching in oil, followed by a retreatment by holding for 30 min at 1450 F, then quenching in brine. The specimen is notched midway and fractured by impact.

The penetration of hardening is measured in 64ths of an inch on half of the fractured sample after grinding and etching lightly in hot 50% hydrochloric acid solution.

The grain size is judged by comparing the surface of the fracture of the hardened case with Shepherd fracture grain-size standards.

The Snyder-Graff Intercept Method for Grain Size—This procedure covers the determination of austenitic grain size in hardened high-speed steels.

To perform the test, a sample is hardened by the recommended procedure and prepared in the usual manner for metallographic examination. The etchant to be used is a mixture of 10% hydrochloric acid, 3% nitric acid, and 87% methyl alcohol by volume. Etching may take from 2 to 10 min, depending on the composition and treatment of the steel.

Grain-size classification is obtained by counting the number of grains intersected by a line 5.0 in. in length at 1000×. The average of ten such counts is the intercept grain count.

Arc-Welding Electrodes

SAE General Information

Report of Iron and Steel and Nonferrous Metals Technical Committees approved October 1946. This SAE General Information Report is a condensation of Tentative Specifications for Iron and Steel Arc-Welding Electrodes, ASTM A 233-45T.

[*As the applications of metal arc welding have greatly increased through the development of new and improved types of electrodes to perform specific jobs most efficiently, and as there are a number of manufacturers each producing his own line of product bearing various trade names, a classification specification for mild-steel electrodes covering a great majority of the electrodes produced was developed by the joint Committee on Filler Metals of the American Welding Society and the American Society for Testing Materials. This specification is identified as ASTM A 233, Specifications for Iron and Steel Arc-Welding Electrodes.*

The following condensed data from the complete specification is included in the SAE Handbook as a general guide to the complete specification for automotive users.]

All of the electrodes, regardless of trade names, which meet all of the requirements of any of these classifications may be expected to have major characteristics which are very similar, if not identical. Certain minor differences continue to exist among brands because of difference in production facilities and the usual differences of opinion which exist in any field regarding specific operating characteristics.

These specifications involve only those requirements necessary to define the major characteristics of each type of electrode involved. Test procedures are used in some instances which do not duplicate production conditions; however, this is not peculiar to this series of specifications alone. Many specifications prescribe special procedures when it is necessary to eliminate variables. In the case of ASTM A 233, some may question the use of the so-called "hot-water procedure" in the welding of the specified butt-joint test assemblies. It is used because it is considered to be the most reliable and easily applied method of obtaining a uniform interpass temperature, regardless of where the work is being done. Control of interpass temperature is necessary since it has an effect upon the mechanical properties obtained from the specimens removed from the test assemblies. The size of test plate, location and number of passes, and stress-relieving procedure are specified for the same reason.

Electrode characteristics which determine its usability for various positions and purposes are: current and voltage range, current characteristics (alternating or direct current, straight or reversed polarity), weld-metal fluidity, mechanical characteristics of deposited weld metal, ability to render a sound weld, and satisfactory weld profile.

The mechanics of the numbering system used in this specification is relatively simple. The letter "E" precedes the number designations involving metal arc-welding electrodes. The first two digits of the electrode classification number designate the minimum allowable tensile strength in the stress relieved condition, in thousands of pounds per square inch. This minimum tensile strength is, of course, to be found in the deposit from the largest diameter electrodes of that group after stress relief. The smaller electrodes of this group might easily have more than the specified minimum tensile strength for the next higher series of classifications, but they would still be in this group.

The number represented by the third and fourth digits designates the positions in which the electrode is useful. As an example of this, reference to the E60 group of the classification table (Table 1) will establish the following facts:

Classification E6010 designates an all-position electrode (in diameters up to and including $^{3}/_{16}$ in. only) useful with direct

TABLE 1—*Minimum Tensile Strength and Ductility Requirements for All-Weld-Metal Tension Test*

ELECTRODE CLASSIFICATION NUMBER	TREATMENT OF WELDED SPECIMEN[a]	TENSION-TEST REQUIREMENTS OF MATERIAL DEPOSITED FROM $^{5}/_{32}$-IN. TO $^{5}/_{16}$-IN. ELECTRODES, INCLUSIVE[b]		
		Min tensile strenth, psi	Min yield point, psi	Min elongation in 2 in., %
E4510	NSR	45,000	Not specified	5
E4520	NSR	45,000	Not specified	5
E6010	SR	60,000	47,000	27
	NSR	62,000	52,000	22
E6011	SR	60,000	47,000	27
	NSR	62,000	52,000	22
E6012	SR	60,000	47,000	22
	NSR	62,000	52,000	17
E6013	SR	60,000	47,000	22
	NSR	62,000	52,000	17
E6020	SR	60,000	47,000	30
	NSR	62,000	52,000	25
E6030	SR	60,000	47,000	30
	NSR	62,000	52,000	25
E7010	SR	70,000	57,000	22
E7011	SR	70,000	57,000	22
E7012	SR	70,000	57,000	18
E7020	SR	70,000	57,000	25
E7030	SR	70,000	57,000	25
E8010	SR	80,000	67,000	19
E8011	SR	80,000	67,000	19
E8012	SR	80,000	67,000	16
E8020	SR	80,000	67,000	22
E8030	SR	80,000	67,000	22
E9010	SR	90,000	77,000	17
E9011	SR	90,000	77,000	17
E9012	SR	90,000	77,000	14
E9020	SR	90,000	77,000	20
E9030	SR	90,000	77,000	20
E10010	SR	100,000	87,000	16
E10011	SR	100,000	87,000	16
E10012	SR	100,000	87,000	13
E10020	SR	100,000	87,000	18
E10030	SR	100,000	87,000	18

[a] The abbreviations SR and NSR signify stress-relieved and non-stress-relieved respectively. Stress-relieving shall be within the range of 1150 ± 25 F for 1 hr per inch of thickness. Specimens shall be heated in a suitable furnace at the rate of 300 to 350 F per hr until a temperature of 1150 ± 25 F has been attained. After this temperature has been reached, it shall be maintained for 1 hr for each inch or fraction thereof of the maximum thickness of the section. The specimens shall be cooled at the same rate specified for heating and may be removed from furnace when the temperature of the plates has reached 300 F.

[b] The tension-test requirements of material deposited from $^{3}/_{4}$-in. electrodes shall be the same as that indicated for $^{5}/_{32}$-in. to $^{5}/_{16}$-in. electrodes, except that the tensile strength and yield point shall be 95% of that prescribed in Table 1.

current, reversed polarity only. This same statement refers to all other "10" classifications, for instance E7010, or E8010.

Classification E6011 is the alternating-current counterpart of the E6010 electrode. This again is an all-position electrode (in diameters up to and including $\frac{3}{16}$ in. only) having the normal-voltage arc and the deep penetration of the E6010 group.

Classification E6012 is also an all-position electrode (in diameters up to and including $\frac{3}{16}$ in. only) useful with alternating current and direct current, either polarity.

Classification E6013 is an all-position electrode characterized by a low-voltage arc with its consequent lack of penetration. This classification of electrode and E6012 are the easiest to use in all positions, particularly because of their ability to bridge gaps.

The E6020 and E6030 classifications are very similar, the latter producing deposits of the maximum fluidity and therefore useful only in flat welding. E6020 electrodes give slightly less fluid deposits and therefore can also be used in the making of horizontal fillets (in diameters up to and including $\frac{1}{4}$ in. only). Obviously, any E6020 electrode will fulfill the requirements of the E6030 class, but the reverse is not true.

The minimum tensile strength and ductility requirements for all-weld-metal tension tests are shown in Table 1 for the various electrode classifications.

E6010, All-Position, Direct Current, Reversed Polarity Only—This class of electrode is designed to produce the best possible mechanical properties consistent with good usability characteristics in all welding positions. It is characterized by a deeply penetrating, forceful, spray-type arc and readily removable, thin friable slag. Fillet welds are usually relatively flat in profile and have a rather coarse, unevenly spaced ripple. The electrode covering is high in cellulose, usually exceeding 30% by weight, which accounts for its being referred to often as the cellulosic type. The other materials generally used in the covering include titanium dioxide, various types of magnesium or aluminum silicates, metallic deoxidizers such as ferromanganese, and liquid sodium silicate. The core wire is usually a rimmed steel containing 0.10–0.14% carbon, 0.40–0.60% manganese, 0.04% maximum sulfur and phosphorus, and 0.025% maximum silicon.

This classification is always recommended for all-position work where the quality of the deposit is of greatest importance, particularly on multipass applications in the vertical and overhead position, where radiographic requirements must be met. While the majority of its applications are on mild steel, it has been used to advantage on galvanized plate and on some low-alloy steels. Sizes larger than $\frac{3}{16}$ in. are not generally used in all positions.

Mechanical properties to be expected when deposited in accordance with the test procedure prescribed in specification are shown in Table 2.

TABLE 2—*Mechanical Properties of E6010 Electrodes*

	AS WELDED	STRESS RELIEVED
Tensile strength, psi	62,000–70,000	60,000–67,000
Yield strength, psi	52,000–58,000	47,000–54,000
Elongation in 2 in., %	22–28	27–34
Reduction of area, %	35	45
Impact resistance, ft-lb, Izod	50–70	
Endurance limit, psi	28,000–32,000	
Density, gm per cc	7.82–7.86	
Brinell hardness	140–160	

Since this type of electrode contains no alloy ingredients other than those usually contained in the core wire, the chemical composition of the deposited metal uncontaminated by plate material will usually show less carbon and manganese than the core wire. The phosphorus and sulfur will not exceed 0.04% each. The silicon content, however, will be higher than that of the core wire and, in the case of some brands, may approach 0.30%.

E6011, All-Position, Alternating and Direct Current, Reversed Polarity—This classification of electrodes is designed to duplicate the usability characteristics and mechanical properties of the E6010 classification using alternating current as the source of power. Although also usable on direct current, reversed polarity, a sacrifice in usability characteristics will be noted when compared to the E6010 electrode. When used with direct current, straight polarity, further sacrifice in usability characteristics is noticed. Penetration, arc action, slag, and fillet-weld appearance are very similar to those of E6010 electrode.

The covering is also high in cellulose. In addition to the other ingredients usually found in the E6010 electrode coverings, small quantities of calcium and potassium are usually present. The core wire used, so far as is known, is identical with that used in E6010 electrodes. This type of electrode has been designed to permit the use of alternating current with its inherent advantages on all of the applications previously possible only with E6010 type electrode and direct current.

The range of mechanical properties to be expected is the same as E6010, although the tensile strength and yield strength are somewhat higher as shown in Table 3.

The chemical composition of deposited metal will fall within the same ranges as described in the section on E6010 electrodes.

TABLE 3—*Tensile and Yield Strengths of E6011 Electrodes*

	AS WELDED	STRESS RELIEVED
Tensile strength, psi	62,000–73,000	60,000–70,000
Yield strength, psi	52,000–61,000	50,000–58,000

E6012, All-Position, Alternating and Direct Current, Straight Polarity—The E6012 type of electrode is characterized by medium penetration, a rather quiet type of arc, slight spatter, and dense slag. The covering is high in titania, usually exceeding 35% by weight, which accounts for the electrode usually being referred to as the Titania or Rutile type. In addition, the covering usually contains various silicious materials such as feldspar and clay, small amounts of cellulose, ferromanganese, and sodium silicate as a binder. Also, small amounts of calcium compound may be used to produce satisfactory arc characteristics on straight polarity. The core wire is identical with that used on E6010 and E6011 type electrodes. Whereas single-pass welds may meet radiographic requirements, multiplass welds fall far short.

Fillet welds tend to be convex in profile, having a smooth even ripple in the horizontal position, and a widely spaced convex ripple in the vertical position which becomes smoother and more uniform as the size of the weld is increased. Ordinarily a larger size fillet must be made in the vertical and overhead positions than with E6010 and E6011 electrodes of the same diameter if good fusion and profile are to be obtained.

Although this is an all-position type, it is only recommended for vertical and overhead work where more ductile weld metal is

considered unnecessary. It is specifically recommended for single-pass horizontal fillet welds where weld-metal quality permits because of the ease of handling, good weld profile, and ability to withstand high welding currents. It is probably the most satisfactory type for work involving poor fit-up. Wide gaps can be bridged quite readily. Its penetration characteristic is too high for best results on stock thicknesses less than 0.1 in.

This electrode has been used to advantage on many low-alloy steels, particularly of the higher carbon varieties. This is probably due to its lower penetration than that obtained with the E6010 or E6011 types, which results in less pickup of alloying ingredients. Higher currents can be used with this type of electrode than can be used with any of the other all-position types.

The weld metal deposited by this electrode is lower in ductility and higher in yield and tensile strength than either E6010 or E6011 electrodes. The range of mechanical properties to be expected when welding in accordance with the test procedures prescribed in the specifications are shown in Table 4.

The chemistry of the deposited metal does not vary very greatly from that obtained from the E6010 or E6011 types. However, microscopic examination will disclose the fact that the weld metal contains far more nonmetallic inclusions.

TABLE 4—*Mechanical Properties of E6012 Electrodes*

	AS WELDED	STRESS RELIEVED
Tensile strength, psi	62,000–78,000	60,000–75,000
Yield strength, psi	52,000–65,000	50,000–60,000
Elongation in 2 in., %	17–22	22–27
Reduction of area, %	25	30
Impact resistance, ft-lb, Izod	25–50	
Endurance limit, psi	Not determined	
Density, gm per cc	7.80–7.85	
Brinell hardness	150–170	

E6013, All-Position, Alternating and Direct Current, Straight Polarity—The E6013 type of electrode, although similar to the E6012, possesses worthwhile differences. Slag removal is somewhat better, and the arc can be established and maintained more readily, particularly in the case of the smaller diameters, thus permitting satisfactory operation with lower open-circuit voltage. This type of electrode was designed specifically for light sheet-metal work. The usability test for this class of electrode is quite successful in selecting the most desirable rods for light sheet-metal work. Even less penetration is obtained than with the E6012 electrode and permits successful welding on much lighter gages.

The coverings used are very similar to those of E6012 containing rutile, silicious materials, cellulose, ferromanganese, and liquid silicate binders. An important difference is that easily ionized materials are incorporated in the coating, which permits the establishment and maintenance of an arc with alternating current at low welding currents and low open-circuit voltages.

It is very similar to the E6012 type in operation and appearance of deposit when used in an identical manner, but the arc tends to be quieter and the deposits more polished in appearance. It is generally recommended for sheet-metal applications where its ability to weld satisfactorily in the vertical position from the top down without leaving surface holes or burning through is an advantage. Small diameters are very satisfactory for air-frame construction in which case the electrode is usually used with direct current, straight polarity. However, because of unsatisfactory performance on galvanized plate and decidedly less penetration E6010 and E6011 classification for this type of electrode is impossible. The range of mechanical properties to be expected when welding in accordance with the test procedures prescribed in the specifications is shown in Table 5.

TABLE 5—*Mechanical Properties of E6013 Electrodes*

	AS WELDED	STRESS RELIEVED
Tensile strength, psi	62,000–72,000	60,000–70,000
Yield strength, psi	52,000–58,000	50,000–56,000
Elongation in 2 in., %	17–22	22–27
Reduction of area, %	30	35
Impact resistance, ft-lb, Izod	Not determined	
Endurance limit, psi	Not determined	
Density, gm per cc	7.80–7.84	
Brinell hardness	140–160	

The chemistry of the deposited metal is very similar to that obtained from the E6012 type. However, the weld metal is definitely less dirty from the standpoint of slag and oxide inclusions.

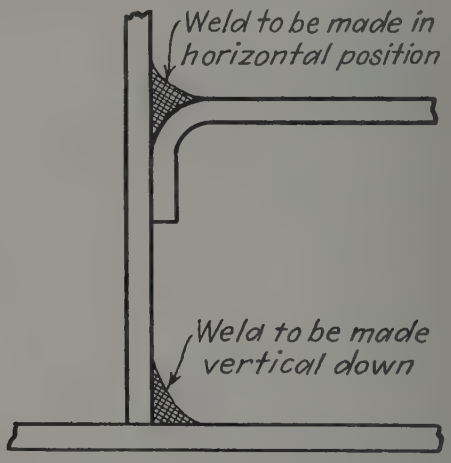


FIG. 1—USABILITY TEST FOR E6013 ELECTRODE

Usability Test, Joint No. 1 for 5/32-In. Electrode—All members are 16 gage metal, 3 x 15 in., and are welded with 5/32-in. electrode. The "T" fillet is to be vertical down and the flange weld is to be horizontal. Both joints are to have not more than 10% draw back or sag on the back of the weld. (See Fig. 1.)

Usability Test, Joint No. 2 for 3/16-In. Electrode—The vertical member of the "T" is to be 16 gage sheet metal and the other two members to be 14 gage. A 3/16-in. electrode is to be used vertical down on the "T" fillet and horizontal on the flange weld. Both joints are to have not more than 10% draw back or sag on the back of the weld. (See Fig. 1.)

This type of electrode must have the following characteristics when used by the average skilled operator.

1. Welds must be sound and of good appearance.
2. Slag must be easily removable.

(*Continued on next page.*)

3. Welds must have complete fusion.

4. Perceptible undercut may not exceed a continuous length of ⅜ in. in any one place.

5. The electrode must be capable of fulfilling the conditions outlined herein and, otherwise, be equally useful on either alternating or direct currents in all welding positions.

6. This type of electrode must be capable of fulfilling the above requirements on all thicknesses of mild steel from light sheet metal to at least ¼-in. plate.

Caution—In cases where electrode is to be rejected, be sure that the steel used in the test is not at fault before final deposition is made. This may be done by duplicating the test on the same material using a previously approved electrode.

E6020, Horizontal Fillets and Flat Position, Alternating and Direct Current—This electrode is designed to produce flat or slightly concave horizontal fillets with either alternating current or direct current and fillets and groove welds in the flat position. It is characterized by a spray-type arc and a heavy slag, well honeycombed on the under side, which completely covers the deposit and can be readily removed.

When normal welding currents and technique are employed, penetration is considered to be medium. However, the electrode is capable of operating satisfactorily at high currents, which results in deep penetration particularly when such a technique is employed as in deep-fillet welding.

This is essentially a mineral-covered electrode. The slag-metal reactions are of such a nature that the electrode does not normally depend on gaseous protection. The covering is such that an iron oxide, manganese oxide, silica slag is usually produced. Other constituents containing the oxides of aluminum, magnesium, or sodium are present to modify the slag. Ferromanganese is used as the main deoxidizer. The quantities of basic oxides, acid silica and silicates, and deoxidizers must be carefully controlled to produce satisfactory operation and good weld metal. Sodium silicate is used as the binder. In most cases the core wire employed is the usual 0.10–0.14% carbon steel. Some exceptions do exist.

This electrode is recommended for horizontal fillet for best quality and where rigid radiographic examination must be met. High deposition rates can be obtained with high quality on flat fillet and groove welds in heavy plate. This type of electrode is not generally used on thin sections because of increased warpage resulting from the higher currents usually employed.

The range of mechanical properties to be expected from the weld metal when deposited in accordance with the test procedures prescribed in the specifications are shown in Table 6.

TABLE 6—*Mechanical Properties of E6020 Electrodes*

	AS WELDED	STRESS RELIEVED
Tensile strength, psi	62,000–68,000	60,000–66,000
Yield strength, psi	52,000–58,000	47,000–53,000
Elongation in 2 in., %	25–30	30–36
Reduction of area, %	40	50
Impact resistance, ft-lb, Izod	50–70	
Endurance limit, psi	30,000–34,000	
Density, gm per cc	7.82–7.86	
Brinell hardness	150–170	

E6030, Flat Position, Direct and Alternating Current—Any electrode designed to fulfill the requirements of the E6020 classification will also fulfill the requirements of the E6030 classification. There are certain other electrodes with which horizontal fillet welding is impractical, if not impossible, but which do operate satisfactorily in the flat position and possess some advantages. As a result, the E6030 classification is necessary.

The slag produced is usually less dense but just as easily removed as that from the E6020 type. When using direct current, best results are obtained with reversed polarity. Generally speaking, this type of electrode is capable of showing higher deposition rates than the E6020 type. The coverings employed are similar to those of the E6020 type.

The range of mechanical properties to be expected from the deposited metal when deposited in accordance with the test procedures prescribed in the specifications are identical with those expected of the E6020 class.

Shot for Peening

SAE Recommended Practice

Report of Production Division approved January 1946 and reassigned to Iron and Steel Technical Committee June 1946.

[*This SAE Recommended Practice provides standard shot-size numbers corresponding to the size of their respective screen apertures for the nominal screen with prefix letter P added. These screens are in accordance with the National Bureau of Standards series as given in ASTM E 11. The shot classifications, size designations, and test procedures were formulated by representatives of the shot and grit suppliers, manufacturers of shot-peening equipment, and automotive users who constituted Division XX on Shot Peening of the Iron and Steel Technical Committee.*]

Shot should be round and solid as it has been found in practice that the round particles stand up better than the irregularly shaped particles.

Maximum "Fines" allowed through smallest screen is 3%. See Table 1. The shot number is roughly the size of the shot pellets in thousandths of an inch. Percentages given are on the basis of weight as determined by the following tests.

Testing Procedure—1. (a) A rotating and tapping type of testing machine shall be used.

(b) The shaking speed shall be 275 to 295 rpm.

(c) The taps per minute shall be 145 to 160, when tapping machines are used.

2. The size of the sample shot shall be 100 gm, to be obtained from a representative quantity.

3. (a) Screening sieves are to be in accordance with the National Bureau of Standards series as provided in ASTM E 11. They shall be of the 8-in. diameter series, of either standard 1-in. or 2-in. height.

(b) The sieves shall be checked as required by testing with master shot samples, using the procedure outlined under Checking of Sieves.

4. The time of test shall be 5 min, plus or minus 5 sec, for shot sizes up to and including U. S. Standard Screen size 35; and 10 min, plus or minus 5 sec, for finer screen sizes.

5. Any alternate method agreed upon between the supplier and user which gives equivalent results will be acceptable.

Checking of Sieves—The sieves shall be checked using master shot samples in accordance with Testing Procedure above.

Master Samples—1. A set of master shot samples shall consist of one sample for each sieve of the series.

2. Each master shot sample shall weigh ½ lb.

3. Each master shot sample shall check 99% between the size of aperture for the *minimum on* screen and the aperture of the next larger size screen. For example, the master shot sample for size P 28 shall check a minimum of 99% between aperture sizes 0.0280 and 0.0331 in.

TABLE 1—*Peening Shot Numbers and Screening Tolerances*[a]

PEENING SHOT NUMBER	HIGH-LIMIT SCREEN		OVERSIZE SCREEN		NOMINAL SCREEN		LOW-LIMIT SCREEN	
	Max shot retained, %	Screen number and aperture	Max shot retained, %	Screen number and aperture	Min shot retained, %	Screen number and aperture	Max shot retained, %	Screen number and aperture
P 157	0	3½ (0.223)	2	4 (0.187)	90	5 (0.157)	5	6 (0.132)
P 132	0	4 (0.187)	2	5 (0.157)	90	6 (0.132)	5	7 (0.111)
P 111	0	5 (0.157)	2	6 (0.132)	90	7 (0.111)	5	8 (0.0937)
P 93	0	6 (0.132)	2	7 (0.111)	90	8 (0.0937)	5	10 (0.0787)
P 78	0	7 (0.111)	2	8 (0.0937)	90	10 (0.0787)	5	12 (0.0661)
P 66	0	8 (0.0937)	2	10 (0.0787)	90	12 (0.0661)	5	14 (0.0555)
P 55	0	10 (0.0787)	5	12 (0.0661)	85	14 (0.0555)	7	16 (0.0469)
P 46	0	12 (0.0661)	5	14 (0.0555)	85	16 (0.0469)	7	18 (0.0394)
P 39	0	14 (0.0555)	5	16 (0.0469)	85	18 (0.0394)	7	20 (0.0331)
P 33	0	16 (0.0469)	5	18 (0.0394)	85	20 (0.0331)	7	25 (0.0280)
P 28	0	18 (0.0394)	5	20 (0.0331)	80	25 (0.0280)	12	30 (0.0232)
P 23	0	20 (0.0331)	5	25 (0.0280)	80	30 (0.0232)	12	35 (0.0197)
P 19	0	25 (0.0280)	5	30 (0.0232)	80	35 (0.0197)	12	40 (0.0165)
P 16	0	30 (0.0232)	5	35 (0.0197)	80	40 (0.0165)	12	45 (0.0138)
P 13	0	35 (0.0197)	5	40 (0.0165)	75	45 (0.0138)	17	50 (0.0117)
P 11	0	40 (0.0165)	5	45 (0.0138)	75	50 (0.0117)	17	60 (0.0098)
P 9	0	45 (0.0138)	5	50 (0.0117)	70	60 (0.0098)	22	70 (0.0083)
P 8	0	50 (0.0117)	5	60 (0.0098)	70	70 (0.0083)	22	80 (0.0070)
P 7	0	60 (0.0098)	5	70 (0.0083)	70	80 (0.0070)	22	100 (0.0059)
P 6	0	70 (0.0083)	5	80 (0.0070)	70	100 (0.0059)	22	120 (0.0049)

[a] Per cent of total sample by weight retained on each pertinent screen.

Shot and Grit for Cleaning

SAE Recommended Practice

Report of Production Division approved January 1946 and last revised by Iron and Steel Technical Committee January 1949.

[*This SAE Recommended Practice provides for standard shot and grit size numbers. For shot, this number corresponds with the aperture size of the nominal screen. For grit, this number corresponds with the number of the nominal screen with the prefix G added. These screens are in accordance with the National Bureau of Standards series as given in ASTM E 11.*

The accompanying shot and grit classifications and size designations were formulated by representatives of shot and grit suppliers, blast-cleaning equipment manufacturers, and automotive users who bonstituted the Shot Peening Division of the Iron and Steel Techcical Committee.]

Shot for Cleaning—Cleaning shot should be round and solid, as it has been found in practice that the round particles stand up better than the irregularly shaped particles.

The shot number is roughly the size of the shot pellets in ten thousandths of an inch. See Table 1.

Testing Procedure—1. (a) A rotating and tapping type of testing machine shall be used.

(b) The shaking speed shall be 275 to 295 rpm.

(c) The taps per minute shall be 145 to 160, when tapping machines are used.

2. The size of the sample shot shall be 100 gm, to be obtained from a representative quantity.

3. (a) Screening sieves are to be in accordance with the National Bureau of Standards series as provided in ASTM E 11. They shall be of the 8-in. diameter series, of either standard 1-in. or 2-in. height.

(b) The sieves shall be checked as required by testing with master shot samples, using the procedure outlined under Checking of Sieves.

4. The time of test shall be 5 min, plus or minus 5 sec, for shot sizes up to and including U. S. Standard Screen size 35; and 10 min, plus or minus 5 sec, for finer screen sizes.

5. Any alternate method agreed upon between the supplier and user which gives equivalent results will be acceptable.

Checking of Sieves—The sieves shall be checked using master shot samples in accordance with Testing Procedure.

Master Samples—1. A set of master shot samples shall consist of one sample for each sieve of the series.

2. Each master shot sample shall weigh ½ lb.

3. Each master shot sample shall check 99% between the size of aperture for the *minimum on* screen and the aperture of the next larger size screen.

Grit for Cleaning—See Table 2.

TABLE 1—*Cleaning Shot Numbers and Screening Tolerances*[a]

SHOT NO.	ON SCREEN	% MAX	THRU SCREEN	ON SCREEN	% MAX	THRU SCREEN	ON SCREEN	% MIN	THRU SCREEN	ON SCREEN	% MAX	THRU SCREEN	% MAX
1320	4 (0.187)	0	—	—	—	4 (0.187)	6 (0.132)	90	6 (0.132)	7 (0.111)	7	7 (0.111)	3
1110	5 (0.157)	0	—	—	—	5 (0.157)	7 (0.111)	90	7 (0.111)	8 (0.0937)	7	8 (0.0937)	3
930	6 (0.132)	0	—	—	—	6 (0.132)	8 (0.0937)	90	8 (0.0937)	10 (0.0787)	7	10 (0.0787)	3
780	7 (0.111)	0	—	—	—	7 (0.111)	10 (0.0787)	85	10 (0.0787)	12 (0.0661)	12	12 (0.0661)	3
660	8 (0.0937)	0	—	—	—	8 (0.0937)	12 (0.0661)	85	12 (0.0661)	14 (0.0555)	12	14 (0.0555)	3
550	10 (0.0787)	0	—	—	—	10 (0.0787)	14 (0.0555)	85	14 (0.0555)	16 (0.0469)	12	16 (0.0469)	3
460	10 (0.0787)	0	10 (0.0787)	12 (0.0661)	5	12 (0.0661)	16 (0.0469)	80	16 (0.0469)	18 (0.0394)	11	18 (0.0394)	4
390	12 (0.0661)	0	12 (0.0661)	14 (0.0555)	5	14 (0.0555)	18 (0.0394)	80	18 (0.0394)	20 (0.0331)	11	20 (0.0331)	4
330	14 (0.0555)	0	14 (0.0555)	16 (0.0469)	5	16 (0.0469)	20 (0.0331)	80	20 (0.0331)	25 (0.028)	11	25 (0.028)	4
230	18 (0.0394)	0	18 (0.0394)	20 (0.0331)	10	20 (0.0331)	30 (0.0232)	75	30 (0.0232)	35 (0.0197)	12	35 (0.0197)	3
170	20 (0.0331)	0	20 (0.0331)	25 (0.028)	10	25 (0.028)	40 (0.0165)	75	40 (0.0165)	45 (0.0138)	12	45 (0.0138)	3
110	30 (0.0232)	0	30 (0.0232)	35 (0.0197)	10	35 (0.0197)	50 (0.0117)	70	50 (0.0117)	80 (0.007)	10	80 (0.007)	10
70	40 (0.0165)	0	40 (0.0165)	45 (0.0138)	10	45 (0.0138)	80 (0.007)	70	80 (0.007)	120 (0.0049)	10	120 (0.0049)	10

[a] Per cent of total sample by weight retained by "on" screen and passed by "thru" screen. The designation 4 (0.187) denotes screen No. 4 with 0.187-in. aperture. Percentages given are on the basis of weight as determined by the test procedure for shot.

(*Continued on next page.*)

TABLE 2—*Cleaning Grit Numbers and Screening Tolerances*

GRIT NUMBER	HIGH-LIMIT SCREEN		NOMINAL SCREEN		LOW-LIMIT SCREEN	
	Max grit retained, %	Screen nnmber and aperture	Min grit retained, %	Screen number and aperture	Max grit to pass, %	Screen number and aperture
G 10	0	7 (0.111)	80	10 (0.0787)	10	12 (0.0661)
G 12	0	8 (0.0937)	80	12 (0.0661)	10	14 (0.0555)
G 14	0	10 (0.0787)	80	14 (0.0555)	10	16 (0.0469)
G 16	0	12 (0.0661)	75	16 (0.0469)	15	18 (0.0394)
G 18	0	14 (0.0555)	75	18 (0.0394)	15	25 (0.0280)
G 25	0	16 (0.0469)	70	25 (0.0280)	20	40 (0.0165)
G 40	0	18 (0.0394)	70	40 (0.0165)	20	50 (0.0117)
G 50	0	25 (0.0280)	65	50 (0.0117)	25	80 (0.0070)
G 80	0	40 (0.0165)	65	80 (0.0070)	25	120 (0.0049)
G 120	0	50 (0.0117)	60	120 (0.0049)	30	200 (0.0029)
G 200	0	80 (0.0070)	55	200 (0.0029)	35	325 (0.0017)
G 325	0	120 (0.0049)	20	325 (0.0017)	—	—

Surface Finish

SAE Standard

Report of Surface Finish Technical Committee approved March 1949. This SAE Standard conforms *in general* with American Standard for Surface Roughness, Waviness, and Lay, ASA B46.1—1947.

General Data—This SAE Standard is concerned with the geometrical irregularities of surfaces of solid materials. It establishes definite classifications for various degrees of roughness and waviness and for several varieties of lay. It also provides a set of symbols for use on drawings, and in specifications, reports, and the like. The ranges for roughness and waviness are divided into a number of steps, and the general types of lay are established by type characteristics.

This Standard does not define what degrees of surface roughness and waviness or what type of lay are suitable for any specific purpose. It does not specify the means by which any degree of such irregularities may be obtained or produced. Neither is it concerned with the other surface qualities such as luster, appearance, color, corrosion resistance, wear resistance, hardness, and microstructure absorption characteristics any of which may be governing considerations in specific applications.

Surfaces in general are very complex in character. Although the height, width, length, shape, and direction of surface irregu-

larities may all be of practical importance in specific applications, this Standard deals only with their height, width, and direction.

Surface roughness by this Standard is predicated on the comparison with SAE master surfaces having known roughness values and having a wide distribution of replicas. Such comparison is to be made by any acceptable method for the surface being measured—for instance, sight, feel, or instruments. Although the master surfaces or replicas therefrom will be the reference standard, instruments may be calibrated to give roughness values.

Definitions (See Fig. 1)—*Surface*—The surface of an object is the boundary which separates that object from another substance. Its shape and extent are usually defined by a drawing or descriptive specification.

Profile—The contour of any specified section through a surface.

Roughness—Relatively finely spaced surface irregularities. On surfaces produced by machining and abrasive operations, the irregularities produced by the cutting action of tool edges and abrasive grains and by the feed of the machine tool are roughness. Roughness may be considered as being superposed on a *wavy* surface.

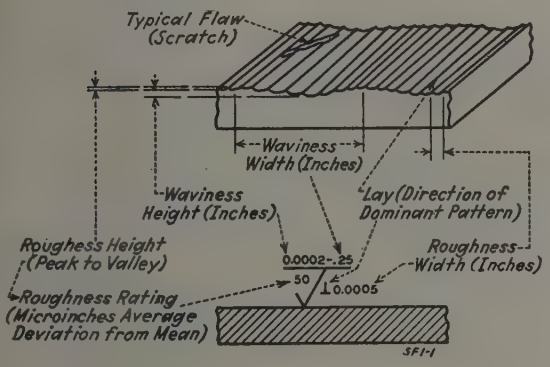


FIG. 1—MEANING OF EACH PART OF SYMBOL DEFINED

Waviness—The surface irregularities which are of greater spacing than the roughness. On machined surfaces such irregularities may result from machine or work deflections, vibrations, or the like. Irregularities of similar geometry may occur due to warping, strains, or other causes.

Flaws—Irregularities which occur at one place or at relatively infrequent intervals in the surface, such as a scratch, ridge, hole, peak, crack, or check.

Lay—The direction of the predominant surface pattern.

Microinch—One millionth of a linear inch (0.000001 in.). This is the unit of height for roughness.

Specification and Rating—*Roughness-Height Rating*—The height of the roughness shall be specified in microinches as the arithmetical average of the absolute deviations from the mean surface. This value will be identified as a roughness number; for example, "16" means that the surface has an arithmetical average absolute deviation from the mean surface of 16 microinches.

Roughness-Width Rating—The maximum permissible spacing of repetitive units of the dominant surface pattern. It may be specified in inches adjacent to the lay symbol. Irregularities having spacings up to and including the maximum specified are rated as roughness width and are to be included in the measurement of roughness height. When no maximum dimension is specified, spacings up to and including the width of the irregularities due to machine feed are rated as roughness width and are to be included in the measurement of roughness height.

Waviness-Height Rating—Waviness heights may be specified directly in inches as the vertical distance from peaks to valleys of the waves.

Waviness-Width Rating—Waviness widths may be specified directly in inches as the distance from peak to peak of the waves.

Lay Specifications—The lay of a surface shall be specified by the lay symbol indicating direction of the dominant visible surface marks.

Measurement or Evaluation—For compliance with specified ratings, surfaces are to be evaluated by comparison with specified reference standards or by direct instrument measurements as described below.

Roughness—Roughness height values will be measured by comparison with SAE master surfaces. Such comparison is to be made by any acceptable method—for instance, sight, feel, or instrument. Although the master surface or replicas therefrom will be the reference standard, instruments may be calibrated to give roughness values directly. For routine measurements, secondary standards may be set up for comparison with SAE master surfaces. In making comparisons care should be exercised to avoid errors due to differences in material, contour, and type of operation represented by the reference surface and the work.

In using instruments for comparison or for direct measurement, care should be exercised to insure that the specified quality or characteristic of the surface is measured.

Roughness measurements, unless otherwise specified, are taken across the lay of the surface or in the direction which gives the maximum value of the reading.

Waviness—Waviness values for height and width may be measured by any suitable device for linear measurement.

Recommended Values of Roughness and Waviness—The use of only one number shall indicate the maximum value of either the height or the width of irregularities. Any less degree shall be satisfactory. When two numbers are used, they shall specify the maximum and minimum permissible values.

SAE Roughness Height Values (Microinches)

1	5	13	32	80	200	500
2	6	16	40	100	250	600
3	8	20	50	125	320	800
4	10	25	63	160	400	1000

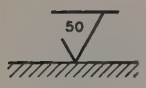
SAE Waviness Height Values (In.)

0.00002	0.00008	0.0003	0.001	0.005	0.015
0.00003	0.0001	0.0005	0.002	0.008	0.020
0.00005	0.0002	0.0008	0.003	0.010	

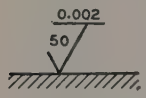
(*Continued on next page.*)

Surface-Finish Symbol—The symbol used to designate surface irregularities is the check mark and extension as shown in Fig. 2.

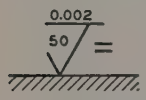
The point of the symbol may be on the line indicating the surface, on a witness line, or on a leader pointing to the surface. The long leg and extension shall preferably be to the right and erect, as the drawing is read.



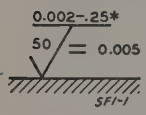
Roughness height value is placed adjacent to and on the inside of the long leg.



Waviness height value, when required, is placed above the extension line.



Lay designation, when required, is indicated by the lay symbol, placed under the extension to the right of the long leg line.



Roughness width value, when required, is placed to the right of the lay symbol.

* When waviness width value is required, the value may be placed to the right of the waviness height value.

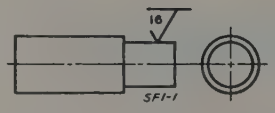
FIG. 2—SURFACE-FINISH SYMBOL

Symbols Indicating Direction of Lay—A lay symbol used with a surface symbol shall specify the direction of the visible pattern of the marks on the surface. See Fig. 3.

Typical examples would be the use of the symbols, as in Figs. 4 and 5, to express the given specifications.

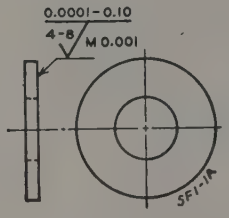
=	Parallel to the surface boundary line indicated by th symbol. *Example:* Parallel shaping, end view of turn and OD Grind.
⊥	Perpendicular to the surface boundary line indicate by the symbol. *Example:* End view of shaping, longitudinal view o turn and OD. Grind.
X	Angular in both directions to the surface boundar line indicated by the symbol. *Example:* Side wheel grind, and traversed end mill.
M	Multidirectional. *Example:* Lap, superfinish.
C	Approximately circular relative to the center of th surface indicated by the symbol. *Example:* Facing.
R	Approximately radial relative to the center of th surface indicated by the symbol.
=.005	The numerical value in inches of the width of spacin of roughness is added to the right of the direction indication in the lay symbol.

FIG. 3—SYMBOLS INDICATING DIRECTION OF LAY



Roughness height = 16 microinche

FIG. 4—SPECIMEN APPLICATION



Roughness height = not more than microinches
not less than microinches
Waviness height = 0.0001 in.
Waviness width = 0.10 in.
Roughness width = 0.001 in.
Lay = multidirectional (lap or super finish)

FIG. 5—SPECIMEN APPLICATION

Copper and Copper-Base Alloys

SAE General Information

Report of Nonferrous Metals Division approved January 1934 and last revised by Nonferrous Metals Technical Committee January 1949.

Sources of Copper—Copper occurs in the native state and in various ores which are found in every continent. The principal sources of domestic supply are Arizona, Michigan, Montana, Nevada, New Mexico, and Utah. Important foreign sources are the Belgian Congo, Canada, Rhodesia, and South America.

Most of the commercial copper reaching the market is processed from ores and electrolytically refined to a purity of 99.90% minimum copper plus silver. Lake copper from northern Michigan is a fire-refined copper of equal purity. Other important sources of fire-refined copper used in wrought products are Arizona and South America, and this copper meets specification requirements of 99.88% minimum copper plus silver.

Types of Copper—Tough pitch copper is copper either electrolytically or fire-refined, cast in the form of refinery shapes, containing a controlled amount of oxygen for the purpose of obtaining a level set in the casting. It generally contains 0.01 to 0.07% oxygen, which exists as a copper oxide eutectic surrounding the crystals of copper. Within the above limits, the oxygen has only a slight effect on the electrical, mechanical, and physical properties of copper. Because of the oxygen's oxidizing effect on other impurities, its presence in copper indicates a reduction or elimination of certain impurities which would otherwise have adverse effects on conductivity.

Oxygen-free copper is copper electrolytically refined and free from cuprous oxide and is produced without the use of residual metallic or metalloidal deoxidizers. Because of its freedom from residual deoxidizers, it has high electrical conductivity.

Deoxidized copper is copper cast in the form of refinery shapes, free from cuprous oxide, produced through the use of metallic or metalloidal deoxidizers. Because it is necessary to use some excess of reducing agent, the electrical and thermal conductivity of the copper is lowered, and this fact should be considered when high conductivity is needed.

Both oxygen-free and deoxidized copper possess only slightly different mechanical properties from the normal types of tough pitch metal. They differ little in respect to tensile strength when cold worked to similar extents but do have higher ductility and also are free from the possibility of hydrogen embrittlement.

Alloy Nomenclature—The two principal copper-base alloys are brass and bronze. Metallurgically they have zinc and tin, respectively, as their other major constituent, and classification of the wrought alloys as one or the other is usually not difficult. However, the nomenclature used in the nonferrous-metals trade may be confusing to those not accustomed to handling these metals since it does not always follow the above definition, but has become so thoroughly established as to be practically impossible to change.

When the term "brass" is used without qualification, it is usually understood to refer to alloys of about two parts copper and one part zinc. Other widely used names for this composition are "yellow brass," "2 and 1 brass," and "high brass." "High brass" indicates a brass of high zinc content, "low brass" one of low zinc content.

True bronzes are the copper-tin alloys, and they are sometimes called "tin bronzes" or "phosphor bronzes." Today it is common practice to use a further qualifying adjective with so-called bronzes to designate the particular alloying element used. For example, aluminum- or manganese-containing alloys are called "aluminum bronze" and "manganese bronze."

Effects of Alloying Elements and Impurities on Copper—The properties of copper are greatly influenced by the presence of comparatively small percentages of many elements. For specialized engineering applications, the presence of small amounts of such elements often determines the most suitable type of copper. For example, where conductivity is the controlling factor, electrolytic copper or low-resistance lake copper should be used, but where it is unimportant as in the manufacture of most alloys, any of the standard refined coppers are satisfactory.

Phosphorus is a widely used, inexpensive, and good deoxidizer of copper, but even traces of phosphorus lower the conductivity materially. (For example, the presence of 0.04% phosphorus reduces the conductivity by about 25%.)

Arsenic in small amounts is present in high-resistance lake copper and is sometimes added to electrolytic copper. Arsenical copper may be either tough pitch or deoxidized. Addition of up to 0.5% arsenic improves the tensile strength both in the annealed and cold-worked conditions and raises the endurance limit as determined by fatigue testing. Arsenic also raises the annealing temperature at which softening first occurs and slightly improves the retention of strength at elevated temperatures. These features have been responsible for the adoption of arsenical copper for such applications as condensers, evaporators, and heat exchangers. The electrical and thermal conductivity of copper containing about 0.25% arsenic is about 50%.

The electrical conductivity of copper is affected to various degrees by impurities other than those mentioned above. The following amounts of impurities reduce the conductivity approximately to the per cent indicated: 0.2% zinc, 99.5%; 0.2% tin, 90%; 0.1% aluminum, 90%; 0.08% iron, 90%; 0.1% nickel, 93%; 0.04% silicon, 90%; 0.2% silicon, 50%; and 0.08% beryllium, 80%. Lead in small amounts has practically no effect on the conductivity.

Additions of silver to copper in amounts of 0.025% (it is normally present in lake coppers) result in a considerable increase of the annealing temperature at which initial softening occurs. An outstanding application of this property is in automobile radiator fins which are subjected to elevated temperatures during fabrication. Silver-free copper necessitates much closer temperature adherence to minimize the danger of softening to a point where fins are easily damaged.

Heat-Treatment—A number of copper-base alloys, both cast and wrought, are capable of being heat treated with considerable resultant increase in physical properties. They are all hardened similarly in that they are given solution treatments followed by a precipitation treatment. The solution treatment consists of heating alloys at high temperatures to dissolve hardening elements in solid solution and cooling at appropriately rapid rates to retain them in solution. The precipitation treatment consists of heating

at a lower temperature to precipitate these unstable phases. Some of the alloys in this category are copper alloys of beryllium, nickel-beryllium, cobalt-beryllium, chromium, nickel-phosphorus, aluminum, and aluminum-nickel-iron. As an example of what can be accomplished by such treatments, copper-beryllium alloys can be readily treated to a Brinell hardness of 400 and copper-cobalt-beryllium to a Brinell hardness of 240.

Joining—Copper and copper-base alloys can be joined by welding, soldering, and brazing. All the welding methods commonly employed are applicable to copper and copper alloys, but all may not be suitable for any one of these metals. The metallurgical and physical properties of the metal to be joined should be considered in selecting the joining method.

With but few exceptions, all the copper-base alloys can be readily soldered or brazed, the choice being influenced by properties desired and cost.

Machining—Pure copper and the solid-solution, single-phase alloys are not readily machinable since they produce long, tough, stringy chips. The addition of lead, tellurium, or selenium to copper alloys makes them extremely free-cutting, and the chips are short and brittle. Intermediate between these two groups are the duplex types of alloys, such as alpha-beta brasses, which can be machined satisfactorily but not as readily as the free-cutting alloys.

Finishing and Coating—Copper and copper-base alloys lend themselves to a large variety of surface finishes and coatings. Finished material can be supplied with polished or buffed surfaces, with bright or matte finishes, with lacquer and enamel coatings, and many other types of surfaces. The preparation of copper and copper-base alloys for electroplating is comparatively simple, and such metals as gold, silver, nickel, and chromium can be readily plated for decorative or tarnish-resistant purposes.

Cast Copper and Copper-Base Alloys

Effect of Alloying Elements and Impurities—*Zinc* is added to copper as a predominating alloying constituent, in amounts of 5 to 40%, to form alloys known as brasses. These groups are called leaded red and semired, silicon, yellow, and high-strength yellow brasses. Zinc imparts a better strength and corrosion resistance to the copper. It is completely soluble in copper, forming solid solution except in such cases as in high-strength yellow brasses in which a duplex type of structure is obtained. Smaller amounts of zinc up to 5% are used in tin bronzes to tighten up the structure and aid in producing sound castings for pressure work. Zinc is not considered a very detrimental impurity in most alloys. However, it is generally kept to below 5% in bearing bronzes because larger amounts would tend to impair bearing qualities.

Tin is added to copper in amounts of 5 to 20% to form a series of alloys known as tin bronzes and leaded tin bronzes. While the copper-tin constitution diagram shows that it is possible to have approximately 16% tin in solid solution, the presence of a hard constituent (alpha-delta copper tin eutectoid) develops in the range of 6 to 8% tin because of deviation from true equilibrium conditions. The tin strengthens and hardens copper, making it tough and resistant to wear and increases its corrosion resistance. Smaller amounts of tin are used in leaded red and semired brasses for increasing the strength of such general utility alloys. Tin is not generally harmful as an impurity except in high-tensile manganese bronze, where it is limited to 0.2% . It is generally felt that in this alloy, tin lowers the strength and ductility.

Lead is added alone to copper in large amounts of around 35% for automotive bearings. In practically all other cases it is added to copper-base alloys as an additional alloying element. Small amounts of lead up to 1.5% increase machinability without important decreases in strength. Larger amounts from 5 to 25% increase machinability greatly, and, in tin-containing alloys increase antifrictional qualities. As an impurity, lead is considered undesirable in high-tensile manganese bronze, silicon bronze, and silicon brass.

Aluminum is added to copper as a predominating alloying constituent to form a series of high-strength alloys known as aluminum bronzes. It is soluble in copper to the extent of about 9.5%. It is added to high-strength yellow brasses in varying amounts being a very necessary part of the high-tensile alloy. Aluminum when present as an impurity, has very detrimental effects upon high leaded bronzes, causing lead sweating and unsoundness during solidification. It is also considered detrimental in the non-leaded tin bronzes, causing unsoundness.

Iron is added to copper-base alloys as a strengthening constituent for silicon, aluminum, and manganese bronzes. It combines with aluminum or manganese or both to form hard compounds. These compounds imbed themselves into the matrix to give the alloys wear resistance. Iron, when present as an impurity is not desirable since it forms hard spots and is detrimental to machining.

Phosphorus is added to copper and copper-base alloys principally as a deoxidizer. It is added to bronzes in greater amounts than necessary for purely deoxidization considerations to improve hardness and wear resistance, particularly in chill mold castings.

Nickel is added to bronzes as an alloying constituent for refining the grain and toughening the alloy. It is also used in amounts of about 15% for nickel brasses to displace that amount of zinc. In this alloy, it promotes strength, corrosion resistance and whiteness. When present as an impurity, it does not have detrimental effects, and most specifications permit approximately 1%.

Silicon is added to copper as an alloying constituent to form copper-silicon alloys. These alloys have high corrosion resistance and high strength and toughness. Small amounts of silicon are used as deoxidizing elements. When silicon is present as an impurity, it is extremely detrimental in leaded tin bronzes, promoting unsoundness and lead sweating.

Beryllium is added to copper as an alloying constituent to form a series of age-hardenable beryllium-copper alloys. These heat-treated alloys are strongest of the known copper-base alloys. They are used for resistance welding electrodes and non-sparking tools. Beryllium is rarely present as an impurity.

Manganese is used primarily as an alloying constituent for high-strength alloy brasses, where it forms compounds with other alloying elements such as iron and aluminum. It is also used, to some extent for deoxidizing. It is not considered very detrimental as an impurity.

Chromium is added to copper as an alloying constituent to form a number of compositions used for resistance welding electrodes. These alloys are heat treated to about 120 Brinell and have an electrical conductivity of about 75%. Chromium is not usually present as an impurity.

Antimony is rarely added to copper-base alloys. When present a

TABLE 1—*Classification and Uses of Commercial Cast Copper-Base Alloys*

ALLOY	SAE[a] NUMBER	NOMINAL COMPOSITION, %					CHARACTERISTICS	TYPICAL APPLICATIONS
		Cu	Sn	Pb	Zn	Others		
Tin Bronzes								
Phosphor Gear Bronze	65	89	11	—	—	0.25P	Hard, strong, tough, resistant to wear (especially with phosphorus), fine-grained (especially with nickel), good machineability (with lead), and corrosion resistant to sea water.	Worm wheels and gears (nickel-bearing and zinc-free for heavy sections). Bushings for heavy loads and low speeds. Zinc-containing alloys for pressure castings.
Nickel Phosphor Gear Bronze	65 + Ni	87	11	—	—	2Ni, 0.2P		
Nickel Phosphor Bronze	640	86.5	11	1.25	—	1Ni, 0.25P		
Gun Metal	62	88	10	—	2	—		
Leaded Gun Metal	63	88	10	1.5	—	0.2P		
Navy "G"	620	88	8	—	4	—		
Leaded Navy "G"	621	87	8	1	4	—		
Navy "M"	622	88.5	6	1.5	4	—		
High Lead Tin Bronzes								
Phosphor Bronze	64	80	10	10	—	—	Excellent anti-frictional qualities and casting and machining properties. Strength and resistance to wear increase with tin content. Anti-friction qualities increase with lead content.	64—High speeds and heavy loads. 660—General bushing applications, medium requirements. 66—High speeds and light loads on bearing backs.
Bronze Bearing	660	83	7	7	3	—		
Bronze Bearing	66	85	5	9	1	—		
Semiplastic Bronze	67	78	6	16	—	—		
High Lead Bronze	—	70	5	25	—	—		
Leaded Red Brasses								
Leaded Red Brass (Ounce Metal)	40	85	5	5	5	—	General utility alloys with reasonable strength and corrosion resistance, good casting and machining properties. Hydro-static tightness increases with zinc content.	Water pump fittings and valve bodies. Ounce metal also used for bearing backs.
Leaded Semired Brass	—	76	3	6	15	—		
High-Strength Yellow Brasses								
Manganese Bronze	43	58	—	—	Rem.	1Fe, 1Al, 1Mn	Excellent strength, corrosion resistance, and casting properties.	Brackets, shafts, gears, and structural applications.
High Tensile Manganese Bronze	430A & B	64	—	—	Rem.	3Fe, 5.5Al, 3.5Mn		
Leaded Yellow Brass								
Yellow Brass	41	67	—	3	Rem.	—	An inexpensive good machining and casting alloy.	Radiator parts, fittings for water cooling systems, and battery terminals.
Aluminum Bronzes								
Aluminum Bronze	68A	88	—	—	—	3Fe, 9Al	Good strength, good corrosion resistance and low coefficient of friction against steel.	Gears, worm wheels, bearings, valve guides and seats, and miscellaneous structural applications.
Aluminum Bronze	68B	88	—	—	—	1.5Fe, 10.5Al		
Copper Silicons								
Silicon Bronze	—	95.5	—	—	—	3Si, 1.5Fe	Good strength, toughness, and corrosion resistance. Casting qualities increase with zinc content.	Pump parts, gears, shafts, and other engineering applications.
Silicon Brass	—	82	—	—	14	4Si		

[a] SAE specifications, where indicated, are those most closely approaching the commercial alloys shown.

an impurity, it is not considered very detrimental in amounts up to 0.5%. If present in greater amounts, it does tend to decrease physical properties.

Wrought Copper and Copper-Base Alloys

Effect of Alloying Elements and Impurities—*Zinc* is added to copper as the predominating alloying constituent to form a series of very widely used alloys known as brasses. These alloys contain up to 42% zinc and their strength increases with increasing amounts of zinc. They are ductile, malleable, corrosion resistant, and have color characteristics ranging from the pink of copper to the yellow of yellow brass. When zinc is not a major alloying element but is present a an impurity, it is usually limited to 0.3% or less, but has little effect.

Tin is added to copper in amounts up to 11% to form a series of alloys known as bronzes. Small amounts of tin are sometimes added to brasses, generally to improve their corrosion resistance. Bronzes are a quality spring material. They are strong, ductile, and corrosion resistant. Their strength can be increased by cold working, and they have a high endurance value as compared to most other nonferrous alloys.

Lead is added to copper in amounts of 1% to form a machinable, high-conductivity copper rod. It is added either to brasses or bronzes in nominal amounts of 0.5–4% to improve machinability and, in the range of 2–4% to improve bearing properties. Lead, present as an impurity in deep-drawing brass above specification limits is undesirable because it affects drawing qualities. In amounts of much over 0.02% it tends to make copper and copper-rich alloys hot short.

Aluminum is added to copper as a predominating alloying constituent to form a series of alloys known as aluminum bronzes. These alloys are of high strength and corrosion resistance and are readily hot worked. When they contain 8% or less aluminum, they are readily cold worked. Aluminum is also added to brass to form an alloy of 76% copper, 22% zinc, 2% aluminum which is used extensively for condenser tubes. Aluminum present as an impurity in brass and other copper alloys is objectionable because small amounts change the annealing temperature, the ductility, and malleability considerably. It is objectionable in bronze welding rods as an impurity because it promotes formation of aluminum oxide during welding, tending to produce a weak joint in the weld metal.

Iron is added to copper as an important alloying constituent along with aluminum in certain aluminum bronzes and with

TABLE 2—*Physical Properties of SAE Wrought Copper Alloys*

	70A–B 74C 80A	70C 74B 80B	701A	701B	701C	71 75 83	72	73 76	77A 81	77C	79A 74D	79B	74A	88
Melting Point (Liquidus), F	1750	1710	1940	1905	1930	1981	1650	1650	1920	1880	1880	1830	1660	1640
Melting Point (Solidus), F	1680	1660	1920	1890	1895	1981	1630	1630	1750	1620	1810	1770	1650	1620
Density at 68 F, lb/cu in	0.308	0.306	0.295	0.275	0.275	0.323	0.307	0.304	0.320	0.318	0.316	0.313	0.303	0.305
Specific Gravity	8.53	8.47	8.17	7.6	7.6	8.94	8.50	8.41	8.86	8.80	8.75	8.67	8.39	8.44
Coef. of Thermal Exp., per F × 10^6, from 68 F to 572 F	11.1	11.3	9.1	9.1	9.1	9.8	11.4	11.8	9.9	10.1	10.4	10.6	11.6	11.5
Thermal Conductivity at 68 F, Btu/sq ft/ft/hr/F	70	67	48	35	22	196	67	67	47	36	92	81	71	69
Thermal Capacity (Sp. Heat) at 68 F, Btu/lb/F	0.09	0.09	0.09	0.09	0.09	0.092	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Electrical Resistivity at 68 F, ohms/mil-ft, (Annealed)	37	38	60	79	88	10.3	40	40	58	80	28	32	37	38
Electrical Conductivity at 68 F on volume basis, % IACS, (Annealed)	28	27	17.5	12.6	11.5	100	26	26	18	13	37	32	28	27
Modulus of Elasticity, million psi, (Annealed)	16	15	15	15	15	17	14	15	16	16	17	16	15	15

TABLE 3—*Fabrication Properties of SAE Wrought Copper Alloys*

	70A–B 74C 80A	70C 74B 80B	701A	701B	701C	71 75 83	72	73	77A 81	77C	79A 74D	79B	74A	88
Cold Working[a]	E	E	G	F	P	E	P	F	E	G	E	E	F	F
Hot Working[a]	F	P	F	G	E	E	F	E	P	P	G	F	E	E
Hot Working Temperature, F	1350–1550	—	1500–1600	1470–1695	1470–1740	1400–1600	1300–1450	1200–1500	—	—	1450–1650	1500–1650	1150–1450	1200–1500
Annealing Temperature, F	800–1400	800–1300	800–1300	800–1400	1150–1650	700–1200	800–1100	800–1100	900–1250	900–1250	800–1350	800–1300	800–1100	800–1100
Machinability (SAE 72 = 100)	30	30	20	30	30	20	100	30	20	20	30	30	40	80
Soft Soldering	E	E	F	F	F	E	E	E	E	E	E	E	E	E
Silver Alloy Brazing	G	G	G	G	G	E	G	G	G	G	E	G	G	G
Oxyacetylene Welding	G	G	F	F	F	F	F	G	G	G	G	G	G	F
Carbon Arc Welding	F	F	F	G	G	G	P	F	G	G	G	F	F	P
Resistance Welding	F	F	F	F	F	P	P	F	G	E	P	P	F	P

[a] E = Excellent G = Good F = Fair P = Poor

TABLE 4—*Classifications and Uses of Commercial Wrought Copper-Base Alloys*

ALLOYS	SAE[a] NO.	NOMINAL COMPOSITION %			CHARACTERISTICS	TYPICAL APPLICATIONS
		Cu	Zn	Others		
Copper-Zinc Alloys					Excellent hot working properties with high copper contents diminishing with decreasing copper (to 65%—the 60% Cu alloy has excellent hot working properties). Excellent pliability and cold working properties with higher copper. Excellent deep drawing properties at 70% copper combined with lowest cost. Alloys vary from red to yellow with decreasing copper content.	Applications vary from jewelry, screen cloth, light sockets, ornamental metal work, and eyelets to large uses such as cartridge cases and automotive radiators. Higher copper alloys for relatively small volume ornamental work and lower copper alloys for high production industrial applications. 60% Cu alloy for heat exchanger tubes.
Gilding–95%		95	5			
Commercial Bronze–90%		90	10			
Red Brass–85%	74D, 79A	85	15			
Low Brass–80%	79B	80	20			
Cartridge Brass	70A, 70B 74C, 80A	70	30			
Yellow Brass	70C, 74B 80B	66	34			
Muntz Metal	74A	60	40			
Free-Cutting Copper-Zinc Alloys					Machinability increases with lead content. Excellent hot working properties of the 60% Cu alloy.	Automatic screw machine parts with high lead. Strip for small stampings requiring free milling qualities with lower lead. 60% Cu alloy for forgings and pressings of all types.
Free Cutting Brass	72	62	35	3Pb		
High Leaded Brass (Clock)		61.5	37	1.5Pb		
Forging Brass	88	60	38	2Pb		
Tin-Bearing Copper-Zinc Alloys					Resistant to salt water corrosion and stronger than straight copper-zinc alloys.	Higher copper for condenser tubes, ferrules. Lower copper for bolts, nuts, piston rods, propeller shafts, etc.
Admiralty Metal		70	29	1Sn		
Naval Brass	73, 76	60	39.25	0.75Sn		
Bushing Bronzes	791	88	4	4Pb, 4Sn	Bearing properties increase with tin and lead contents.	Clutch pedal shaft bushings and piston pin bushings.
	795	90	9.5	0.5Sn		
Phosphor Bronzes	77A, 81	95		0.1P 5Sn	High strength, yield point, and fatigue resistance. Strength increases with higher tin and degree of cold working.	Parts requiring copper base alloy with spring characteristics.
	77C	92		0.1P 8Sn		
Aluminum Bronzes	701A	95		5Al	High strength, good corrosion resistance, low coefficient friction against steel. Physical properties increase with increasing alloy content.	Gears, sleeves, screws, forming mandrels, bushings, fabricated sections, spark plug inserts.
	701B	87		8Al 5Fe, Si, Mn		
	701C	82		10Al, 5Ni, 3Fe		
Copper-Silicon Alloy		96		3Si 1 of Fe, Mn, Sn, or Zn	Corrosion resisting properties of copper and physical properties of mild steel. Readily cold or hot worked	Marine hardware, chemical equipment, hydraulic pressure lines, heat exchanger tubes.

[a] SAE specifications, where indicated, are those most closely approaching the commercial alloys shown.

manganese in certain manganese bronzes. It is also added to alloys similar to the cupro nickels to increase corrosion resistance, and it is present in small amounts in some welding rods. Iron present as an impurity in deep drawing alloys is very detrimental. It is detrimental in brasses because it seriously affects the annealing temperatures.

Phosphorus is added to copper and copper-base alloys principally as a deoxidizer. It may be added to bronzes in greater amounts than necessary just for deoxidization to improve spring properties. It is used in certain low-melting brazing-rod compositions in amounts up to 7%.

Nickel is added to copper as an alloying constituent forming the cupro-nickel series of alloys. These alloys have high strength without loss of ductility. They have excellent corrosion resistance and are white in color. Nickel is added to brasses to form a series of alloys known as nickel silvers. Nickel and phosphorous are alloyed with copper, and nickel is added to certain aluminum bronzes forming series of heat-treatable alloys. Nickel present as an impurity in copper-base alloys is not considered detrimental.

Silicon is added to copper as an alloying constituent to form the copper-silicon series. These alloys have high corrosion resistance combined with high strength and superior welding qualities. Small amounts of silicon are used as deoxidizers.

Beryllium is added to copper as an alloying constituent to form a series of age-hardenable beryllium-copper alloys. In the fully treated condition, beryllium copper is the strongest of the known copper-base alloys and has an electrical conductivity of about 20%. It is used in high-quality spring applications. The hardnesses are such that the alloys can be used for tools where

nonsparking qualities are desired. Beryllium is not normally present as an impurity.

Manganese is added to copper primarily as a desulfurizing and degassifying element for alloys containing nickel. It is used in amounts of approximately 0.6% in copper-alloy brazing and welding rods. Generally speaking, manganese is not harmful when present as an impurity.

Chromium is added to copper as an alloying constituent to form a number of compositions used for resistance welding electrodes. The alloy is heat treated and cold drawn to a hardness of about 140 Brinell and an electrical conductivity of about 80%. This hardness is retained at elevated temperatures up to about 900 F. Chromium is not usually present as an impurity.

Antimony is rarely added to copper-base alloys. It is used, to a limited extent, in admiralty alloys and aluminum brasses as an inhibitor against dezincification. It increases the annealing temperature of copper. Antimony, when present as an impurity, promotes brittleness.

Tellurium or Selenium is added to copper and copper-base alloys in amounts up to 1% to improve machinability.

Working and Annealing—Copper and copper-base alloys can, with some exceptions, be worked either hot or cold, and frequently both methods are combined in order to produce a finished product. Hot working is defined as the plastic deformation of a metal at a temperature sufficiently high to prevent strain hardening or, as more commonly stated, it is the working of a metal above the recrystallization temperature. The normal hot-working temperatures for copper alloys vary from 1200 to 1750 F, depending upon the composition and type of operation being used. Such alloys as leaded alpha brasses and leaded tin bronzes cannot be hot worked because of their hot short characteristics at elevated temperatures.

The ability of a metal to be cold worked depends on its mechanical properties such as tensile strength and ductility—the latter being particularly important since without ductility, no cold work can be done. The effect of cold work is to increase the tensile strength and yield strength and to reduce the elongation and reduction of area. The copper-base alloys, like other metals, will stand only a certain amount of cold working, beyond which breaking is apt to occur; hence, for severe amounts of cold working, intermediate annealing becomes necessary. The annealing temperatures will vary from 800 to 1400 F, depending upon the composition of the alloy, the amount of cold work, and the degree of softness required.

Testing and Selection of Wrought Alloys—Standard specimens of wrought material shall be taken parallel to the direction of rolling, and all rods, bars, and shapes shall be tested in full size when practicable. In materials 1½ in. and larger in diameter or thickness, the center or cross-section of the test specimen shall be half way between the center and outer surface of the piece unless otherwise specified.

Unless otherwise noted, the yield strength shall be determined as the stress producing an elongation of 0.5% under load; that is, 0.01 in. in a gage length of 2 in.

Grain size is to be determined by the Jeffries method at 75 magnifications. See ASTM E2, Standard Methods of Preparation of Micrographs of Metals and Alloys.

The specifications accompanying this text cover a large number of tempers and anneals. Many times it is difficult to determine the most suitable condition necessary for the specific operation or the requirements are too particular to be specified by any of the ordinary physical tests. It is then frequently advisable to submit samples or drawings to the manufacturer and secure an adjustment of anneal or temper to suit the actual operations.

Copper-Base Casting Alloys

SAE Standard

Report of Nonferrous Metals Division approved June 1911 and last revised by Nonferrous Metals Technical Committee January 1950.

TABLE 1—*Composition of Copper-Base Casting Alloys*[a]

SAE No.	ALLOY	ELEMENTS[b], PER CENT BY WEIGHT[c]										
		Copper	Tin	Lead	Zinc	Iron	Nickel	P	Al	Si	Sb	Mg
40	Leaded Red Brass	**84.0–86.0**	**4.0–6.0**	**4.0–6.0**	4.0–6.0	0.30	**1.0**	—	0.005	0.005	—	—
41	Yellow Brass	**65.0–70.0**	**1.5**	**1.5–3.75**	Bal.	0.75	—	—	0.30	—	—	—
43	Manganese Bronze	**55.0–60.0**	1.0	**0.40**	Bal.	**0.40–2.0**	0.50	—	**0.5–1.5**	—	—	**1.5**
430A, **430B**	High Tensile Manganese Bronze	**60.0–68.0**	0.20	**0.20**	Bal.	**2.0–4.0**	0.50	—	**3.0–7.5**	—	—	**2.5–5.0**
62	Gun Metal	**86.0–89.0**	**9.0–11.0**	**0.30**	1.0–3.0	0.15	**1.0**	—	0.005	—	—	—
620	Navy "G"	**86.0–89.0**	**7.5–9.0**	**0.30**	3.0–5.0	0.15	**1.0**	—	0.005	—	—	—
621	Leaded Navy "G"	**85.0–89.0**	**7.5–9.0**	**1.0**	3.0–5.0	0.25	**1.0**	—	0.005	—	—	—
622	Navy "M"	**86.0–90.0**	**5.5–6.5**	**1.0–2.0**	3.0–5.0	0.25	**1.0**	—	0.005	—	—	—
63	Leaded Gun Metal	**86.0–89.0**	**9.0–11.0**	**1.0–2.5**	0.75	0.15	**1.0**	0.25	0.005	—	—	—
64	Phosphor Bronze	**78.0–82.0**	**9.0–11.0**	**8.0–11.0**	0.75	0.15	**0.50**	0.25	0.005	0.005	0.50	—
640	Nickel Phosphor Bronze	**85.0–88.0**	**10.0–12.0**	**1.0–1.5**	0.50	0.30	**0.75–1.5**	**0.20–0.30**	0.005	—	—	—
65	Phosphor Gear Bronze	**88.0–90.0**	**10.0–12.0**	**0.50**[d]	**0.50**[d]	0.15	[d]	**0.10–0.30**	0.005	—	—	—
66	Bronze Bearings	**83.0–86.0**	**4.5–6.0**	**8.0–10.0**	2.0	0.20	**0.50**	—	0.005	0.005	0.30	—
660	Bronze Bearings	**81.0–85.0**	**6.25–7.5**	**6.0–8.0**	2.0–4.0	0.20	**0.50**	0.15[e]	0.005	0.005	0.25	—
67	Semiplastic Bronze	**76.5–79.5**	**5.0–7.0**	**14.0–18.0**	1.5	0.40	**0.75**	**0.05**	0.005	0.005	0.50	—
68A	Aluminum Bronze—As Cast[f]	**86.0–89.0**	**0.50**	—	—	**2.5–4.0**	—	—	**8.5–9.5**	—	—	—
68B	Aluminum Bronze—As Cast or Heat-Treated	**86.0–89.0**	**0.20**	—	—	**1.0–2.0**	—	—	**10.0–11.5**	—	—	—

[a] See SAE General Information on Bearing and Bushing Alloys for additional alloys. This table refers to castings only, not to ingots.
[b] Elements in bold face type regularly require analysis. All values not given as ranges are maximum.
[c] Samples for analysis should be taken from test bars where possible.
[d] Total lead, zinc, and nickel is 1.0% maximum.
[e] Maximum of 0.50% phosphorus is permissible for permanent mold castings only.
[f] Sum of named elements is 99.0% minimum.

TABLE 2—*Physical Properties and Similar Specifications of Copper-Base Casting Alloys*

SAE Number	MINIMUM PHYSICAL PROPERTIES[a]			SIMILAR SPECS.		
	Tensile strength, psi	Yield strength, psi	Elongation, per cent in 2 in.	ASTM No.	ASTM Alloy	AMS[b]
40	30,000	—	20	B145, B62	4A	4855
41	30,000	—	20	B146	6B	—
43	65,000	25,000	20	B147	8A	4860
430A	90,000	45,000	20	B147	8B	—
430B	110,000	60,000	12	B147	8C	4862
62	40,000	—	20	B143	1A	4845
620	40,000	—	20	B143	1B	—
621	36,000	—	18	B143	2B	—
622	34,000	—	22	B143	2A	—
63	35,000	—	10	—	—	—
64	25,000	—	8	B144	3A	4842
640	35,000	—	10	—	—	—
65	35,000	—	10	—	—	—
66	25,000	—	8	B144	3C	—
660	30,000	—	12	B144	3B	—
67	20,000	—	10	B144	3D	—
68A (as cast)	65,000	25,000	20	B148	9A	—
68B (as cast)	65,000	25,000	20	B148	9B	—
68B (heat-treated)	80,000	50,000	4	—	—	—

[a] Test bars shall be cast in sand molds from the same heat or series of heats from which the castings are made. See corresponding ASTM specification for type of bar and ASTM E – 8 for method of determining yield strength.
[b] SAE Aeronautical Material Specifications.

Wrought Copper-Base Alloys — SAE Standard

Report of Nonferrous Metals Division approved June 1911 and last revised by Nonferrous Metals Technical Committee January 1951.

TABLE 1—*Chemical Compositions of SAE Wrought Copper-Base Alloys*

SAE No.	NAME	ELEMENTS, PER CENT BY WEIGHT[a]					OTHER ELEMENTS
		Cu	Sn	Pb	Fe	Zn	
70A, 70B	Cartridge Brass Sheet and Strip	68.5–71.5	—	0.07	0.05	Rem	—
70C	Yellow Brass Sheet and Strip	64.0–68.0	—	0.15	0.05	Rem	—
701A	Aluminum Bronze Rods, Bars, and Shapes	92.0–96.0	—	—	0.50	—	4.00–7.00 Al, 0.50 Others
701B	Aluminum Bronze Rods, Bars, and Shapes	80.0–93.0	0.60	—	4.00	—	6.50–11.00 Al, 1.00 Ni, 1.50 Mn, 2.25 Si, 0.50 Others
701C	Aluminum Bronze Rods, Bars, and Shapes	78.0–85.0	0.20	—	2.00–4.00	—	9.00–11.00 Al, 4.00–5.50 Ni, 1.50 Mn, 0.25 Si, 0.50 Others
71	Copper Sheet and Strip	99.9 Min	—	—	—	—	—
72	Free-Cutting Brass Rods	60.0–63.0	—	2.50–3.75	0.15	Rem	0.50 Others
73	Naval Brass Rods, Bars, Forgings, and Shapes	59.0–62.0	0.50–1.00	0.20	0.10	Rem	0.10 Others
74A	Seamless Brass Tubes (Muntz Metal)	59.0–63.0	—	0.80	0.07	Rem	—
74B	Seamless Brass Tubes (Yellow Brass)	65.0–68.0	—	0.80	0.07	Rem	—
74C	Seamless Brass Tubes (Cartridge Brass)	68.5–71.5	—	0.07	0.05	Rem	—
74D	Seamless Brass Tubes (Red Brass, 85%)	83.0–86.0	—	0.06	0.05	Rem	—
75	Copper Tubes	99.9 Min	—	—	—	—	—
76	Naval Brass Tubes	59.0–62.0	0.50–1.00	0.30	0.10	Rem	0.10 Others
77A	Phosphor Bronze Sheet and Strip[b]	—	3.50–5.80	0.05	0.10	0.30	0.03–0.35 P, 0.01 Sb
77C	Phosphor Bronze Sheet and Strip[b]	—	7.00–9.00	0.05	0.10	0.20	0.03–0.25 P, 0.01 Sb
79A	Red Brass, 85%, Sheet and Strip	84.0–86.0	—	0.05	0.05	Rem	—
79B	Low Brass, 80%, Sheet and Strip	78.5–81.5	—	0.05	0.05	Rem	—
791	Bushing Alloy	Rem	3.5 –4.5	3.5 –4.5	0.10	1.5–4.0	0.20 Others
795	Bushing Alloy	88.0–92.0	0.25–0.75	—	0.10	Rem	0.20 Others
80A	Cartridge Brass Wire	68.5–71.5	—	0.07	0.05	Rem	—
80B	Yellow Brass Wire	63.0–67.5	—	0.10	0.05	Rem	—
81	Phosphor Bronze Wire and Rod[b]	—	3.50–5.80	0.05	0.10	0.30	0.03–0.35 P, 0.01 Sb
83	Copper Wire (Annealed)[c]	—	—	—	—	—	—
88	Forging Brass Rod	58.0–62.0	—	1.50–2.50	0.30	Rem	—

[a] All values not given as ranges are maximums unless otherwise noted.
[b] Minimum total of copper, tin, and phosphorous shall be 99.5%.
[c] SAE 83 copper wire shall be of such quality and purity that when drawn and annealed, it shall have the physical and electrical properties defined in its specification in this standard.

SAE 70—Brass Sheet and Strip

Chemical Composition

	70A (70B)[1] Cartridge Brass	70C Yellow Brass
Copper, %	68.5–71.5	64.0–68.0
Lead, %	0.07 max	0.15 max
Iron, %	0.05 max	0.05 max
Zinc	Remainder	Remainder

[1] The designation 70B is eventually to be dropped. The composition was replaced by SAE 70A in February 1947, but the identity was retained for information only.

Physical Properties

Tensile Properties—The tensile strength of rolled sheet of various tempers shall conform to Table 1. The Rockwell hardness values are shown in Table 2 for information only.

Annealed Temper Properties—Designations for degree of anneal shall be in terms of average grain diameter in millimeters and shall conform to the limits specified in Table 3. The Rockwell hardness values are shown in Table 3 for information only.

Dimensional Tolerances—Dimensions of thickness, width, straightness, and length shall be within the limits shown in Tables 1, 6, 8, and 9, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Common Forms and Tempers—

SAE 70A and 70B

Flat Products—0.015 through 0.100 mm anneal and quarter hard through extra-spring temper.

SAE 70C

Flat Products—0.015 through 0.070 mm anneal and one-eighth hard through spring temper.

Typical Uses—

Automotive—Radiator cores and tanks, headlamp reflectors.

Electrical—Bead chain, flashlight shells, lamp fixtures, socket shells, screw shells.

Hardware—Eyelets, fasteners, springs, stampings.

Common Fabrication Processes—Blanking, drawing, etching, forming and bending, heading and upsetting, piercing and punching, shearing, spinning, squeezing and swaging, stamping.

Similar Specifications—SAE 70A is similar to ASTM B 36,

Alloy 6; and AMS 4505 and 4507. SAE 70C is similar to ASTM B 36, Alloy 8.

TABLE 1—*Tensile Strength of SAE 70 in Psi*

TEMPER	GRADES A AND B		GRADE C	
	Min	Max	Min	Max
Quarter Hard	49,000	59,000	49,000	59,000
Half Hard	57,000	67,000	55,000	65,000
Three-Quarters Hard	64,000	74,000	62,000	72,000
Hard	71,000	81,000	68,000	78,000
Extra Hard	83,000	92,000	79,000	89,000
Spring	91,000	100,000	86,000	95,000
Extra Spring	95,000	104,000	90,000	99,000

TABLE 2—*Rockwell Hardness of SAE 70*[a]

TEMPER	GRADES A AND B				GRADE C			
	B Scale		30-T Scale		B Scale		30-T Scale	
	Min	Max	Min	Max	Min	Max	Min	Max
Quarter Hard	40	65	43	60	40	65	43	60
Half Hard	60	77	56	68	57	74	54	66
Three-Quarters Hard	72	82	65	72	70	80	65	71
Hard	79	86	70	74	76	84	68	73
Extra Hard	85	91	74	77	83	89	73	76
Spring	89	93	76	78	87	92	75	78
Extra Spring	91	95	77	79	88	93	76	79

[a] B Scale applies to metal 0.020-in. thick and over. 30-T Scale applies to metal 0.012-in. thick and over.

TABLE 3—*Grain Size and Rockwell Hardness*[a] *of SAE 70 (Annealed Temper)*

ANNEALING DESIGNATION, MM	AVERAGE GRAIN SIZE, MM		F SCALE		30-T SCALE	
	Min	Max	Min	Max	Min	Max
0.015	—[b]	0.025	72	85	33	50
0.025	0.015	0.035	67	79	27	42
0.035	0.025	0.050	65	76	25	38
0.050	0.035	0.070	61	73	20	35
0.070	0.050	0.100	52	67	3	27
0.120	0.070	—	50	62	—	21

[a] F Scale applies to metal 0.020-in. thick and over. 30-T Scale applies to metal 0.015-in. thick and over.
[b] Must be fully recrystallized.

SAE 701—Aluminum Bronze Rods, Bars, and Shapes

Chemical Composition

	701A	701B[a]	701C
Copper, %	92.0–96.0	80.0–93.0	78.0–85.0
Aluminum, %	4.0– 7.0	6.5–11.0	9.0–11.0
Iron, %	0.50 max	4.00 max	2.0– 4.0
Nickel, %	—	1.00 max	4.0– 5.5
Manganese, %	—	1.50 max	1.50 max
Silicon, %	—	2.25 max	0.25 max
Tin, %	—	0.60 max	0.20 max
Other elements, Total, %	0.50 max	0.50 max	0.50 max

[a] When both nickel and silicon are present, only one shall be in excess of 0.25%.

Physical Properties

Tensile Properties—No tensile properties are normally specified for SAE 701A. The tensile properties of various bar sizes of alloys SAE 701B and 701C shall conform to Tables 1 and 2.

Bend Test—Grades A and B shall bend cold, without fracture on the outside of the bent portion, through an angle of 120 deg around a pin, the diameter of which is equal to twice the diameter of round rod or four times the thickness of bar or other shapes.

Season Cracking Test—A full-size test specimen must stand immersion for 15 min without cracking in an aqueous solution containing 100 g of mercurous nitrate and 13 cc of nitric acid (specific gravity 1.42) per l. For further details see ASTM B 154.

Dimensional Tolerances—Dimensions of diameter, thickness, and width shall be within the limits shown in Tables 11, 4, and 7, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Typical Uses—SAE 701 is commonly used for bushings, gears, valve parts, bearings, sleeves, screws, pins, and fabricated sections. This alloy is also applicable where strength at elevated temperatures, a low coefficient of friction against steel, or a combination of strength and corrosion resistance is required.

Common Fabrication Processes—Machining, forging, and welding.

Similar Specifications—SAE 701A is similar to ASTM B 124, Alloy 10, which comes in forgings, rods, bars, and shapes. SAE 701B is similar to ASTM B 150, Alloy 1; and to AMS 4631 and 4635. SAE 701C is similar to ASTM B 150, Alloy 2; and to AMS 4640.

TABLE 1—*Tensile Properties of SAE 701B*

SIZE	MINIMUM TENSILE STRENGTH, PSI	MINIMUM YIELD STRENGTH, PSI	MINIMUM ELONGATION IN 2 IN., %
Rods and Bars, thickness or diameter in in.			
over to and including			
0 0.50	80,000	40,000	15
0.50 1.00	75,000	37,500	15
1.00	72,000	35,000	20
Shapes, all sizes	70,000	30,000	15

TABLE 2—*Tensile Properties of SAE 701C*

DIAMETER OF ROUNDS, IN.		MINIMUM TENSILE STRENGTH, PSI	MINIMUM YIELD STRENGTH, PSI	MINIMUM ELONGATION IN 2 IN., %
Over	To and Including			
0.50	1.00	100,000	50,000	10
1.00	2.00	90,000	45,000	12
2.00	3.00	85,000	42,500	15

SAE 71—Copper Sheet and Strip

Chemical Composition

Copper, % 99.90 minimum

There are two types of copper sheet used in the automotive industry: electrolytic tough pitch and silver-bearing tough pitch.

Silver-bearing tough pitch may be lake copper, or it may be produced from electrolytic copper by the addition of the correct amount of silver. The silver content is normally specified in troy ounces per avoirdupois ton (one ounce per ton being equal to 0.0034%). The desired minimum silver content must be specified. The usual amount of silver is 6 to 10 oz, which is sufficient to raise the recrystallization temperature appreciably.

Physical Properties

Tensile Properties—The tensile strength of sheet and strip in cold- and hot-rolled tempers shall conform to Table 1. The Rockwell hardness values are shown for information only.

Annealed Temper Properties—Grain-size requirements for cold-rolled annealed tempers shall conform to Table 2. The Rockwell hardness values are shown for information only.

Dimensional Tolerances—Dimensions of thickness, width, straightness, and length shall be within the limits shown in Tables 1, 6, 8, and 9, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Common Forms and Tempers—
Flat products—0.050 mm, 0.025 mm, one-eighth hard, quarter hard, half hard, hard, extra hard, spring, extra spring, and hot-rolled.

Typical Uses—
Architectural—Building fronts, downspouts, flashing, gutters, roofing.
Automotive—Gaskets, radiators.
Electrical—Contacts, radio parts, switches, terminals.
Miscellaneous—Chemical process equipment, kettles, pans, rotating bands, vats.

TABLE 1—*Tensile Strength and Hardness of SAE 71*

	TENSILE STRENGTH, PSI		ROCKWELL HARDNESS[a]					
			B Scale		F Scale		30-T Scale	
	Min	Max	Min	Max	Min	Max	Min	Max
Light cold-rolled	32,000	40,000	—	39	40	82	—	49
Half hard	37,000	46,000	30	50	77	89	43	57
Hard	43,000	52,000	45	57	86	93	54	62
Spring	50,000	58,000	54	64	91	97	60	66
Extra spring	52,000	—	56	—	92	—	61	—
Hot-rolled	30,000	38,000	—	—	—	75	—	41
Hot-rolled and annealed	30,000	38,000	—	—	—	65	—	31

[a] B and F Scales apply to metal 0.020-in. thick and over. 30-T Scale applies to metal 0.012-in. thick and over.

TABLE 2—*Grain Size and Hardness of SAE 71 (Cold Rolled)*

TEMPER	GRAIN SIZE, MM		ROCKWELL HARDNESS[a]			
			F Scale		15-T Scale	
	Min	Max	Min	Max	Min	Max
Soft anneal	—[b]	—	—	65	—	68
Deep drawing anneal (0.025 mm)	—[b]	0.050	30	75	44	73

[a] F Scale applies to metal 0.020-in. thick and over. 15-T Scale applies to metal 0.015-in. thick and over.
[b] Material must be fully recrystallized.

Common Fabrication Processes—Blanking, coining, drawing, etching, impact extrusion, piercing and punching, shearing, spinning, squeezing and swaging, stamping.

Similar Specifications—SAE 71 is similar to ASTM B 152 ETP and STP, and to AMS 4500.

SAE 72—Free Cutting Brass Rod

Chemical Composition

Copper, %	60.0–63.0
Lead, %	2.5–3.7
Iron, %	0.15 max
Total other impurities, %	0.50 max
Zinc	Remainder

Physical Properties

Tensile Properties—The tensile properties of soft and half-hard rods shall conform to Table 1.

Bend Test—Rods or bars in half-hard temper shall bend cold, without fracture, through an angle of 120 deg around a pin, the diameter of which is equal to twice the diameter of round rod or four times the thickness of bar or other shape. The bend test may be waived upon agreement between the purchaser and the manufacturer.

Dimensional Tolerances—Dimensions of diameter or distance between parallel surfaces and length shall be within the limits

TABLE 1—*Physical Properties of SAE 72*

CONDITION	MINIMUM TENSILE STRENGTH, PSI	MINIMUM YIELD STRENGTH, PSI	MINIMUM ELONGATION IN 2 IN., %
Soft			
through 1.000 in.	48,000	20,000	20
1.001–2.000 in.	44,000	18,000	25
2.001 in. and over	40,000	15,000	30
Half Hard (Rounds, Hex., Oct.)			
through 0.500 in.	57,000	25,000	7
0.501–1.000 in.	55,000	25,000	15
1.001–2.000 in.	50,000	20,000	20
2.001 in. and over	45,000	15,000	25

TABLE 2—*Physical Properties of SAE 72 Rectangles and Squares*

TEMPER	THICKNESS, IN.	WIDTH, IN.	MINIMUM TENSILE STRENGTH, PSI	MINIMUM YIELD STRENGTH, PSI	MINIMUM ELONGATION IN 2 IN., %
Soft	1 and under	6 and under	44,000	18,000	20
	Over 1	6 and under	40,000	15,000	25
Half Hard	½ and under	1 and under	50,000	25,000	10
	½ and under	Over 1 to 6	45,000	17,000	15
	Over ½ to 2	2 and under	45,000	17,000	20
	Over ½ to 2	Over 2 to 6	40,000	15,000	20
	Over 2	Over 2 to 4	40,000	15,000	20

shown in Tables 11 and 10, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Common Forms and Tempers—
Flat Drawn Bars—Quarter hard, and half hard.
Rods—Soft anneal, half hard.
Shapes—Quarter hard, half hard, and extruded.

Typical Uses—Small screw-machine parts, pins, nuts, plugs, screws, valve discs, and caps.

Common Fabrication Processes—Machining, roll threading, and knurling.

Similar Specifications—SAE 72 is similar to ASTM B 16 and to AMS 4610.

SAE 73— Naval Brass Rods, Bars, Forgings, and Shapes

Chemical Composition

Copper, %	59.0–62.0
Tin, %	0.50–1.00
Lead, %	0.20 max
Iron, %	0.10 max
Total other impurities	0.10 max
Zinc	Remainder

Physical Properties

Tensile Properties—The tensile properties of various shapes and tempers shall conform to Table 1.

TABLE 1—*Tensile Properties of SAE 73*

CONDITION	MINIMUM TENSILE STRENGTH, PSI	MINIMUM YIELD STRENGTH, PSI	MINIMUM ELONGATION IN 2 IN., %
Rods and Bars, Soft			
through 1.000 in.	54,000	20,000	35
1.001 to 2.500 in.	52,000	20,000	40
2.501 in. and over	50,000	20,000	40
Rods and Bars, Half Hard			
through 0.500 in.	60,000	27,000	25
0.501 to 1.000 in.	60,000	27,000	30
1.001 to 2.500 in.	58,000	26,000	30
2.501 to 3.500 in.	54,000	25,000	30
3.501 in. and over	54,000	22,000	30
Rods and Bars, Hard			
through 1.000 in.	67,000	45,000	17
1.001 to 2.500 in.	62,000	37,000	25
2.501 to 3.500 in.	54,000	25,000	30
3.501 in. and over	54,000	22,000	30
Soft Shapes, all sizes	56,000	22,000	30
Hot Pressed Forgings	55,000	—	35

Bend Test—Rods, bars, or shapes in soft condition shall bend cold through an angle of 180 deg, and rods and bars in half-hard or hard condition shall bend cold through an angle of 120 deg without fracture. Bends are to be made around a pin the diameter of which is two times the diameter of round rod or four times the thickness of bar or other shape. The bend test may be waived upon agreement between the purchaser and the manufacturer.

Season Cracking Test—A full-size test specimen must stand immersion for 15 min without cracking in an aqueous solution containing 100 g of mercurous nitrate and 13 cc of nitric acid (specific gravity 1.42) per l. For further details see ASTM B 154.

Dimensional Tolerances—Dimensions of diameter or distance between parallel surfaces; thickness and width of rectangular bars; and length of rods, bars, and shapes, shall be within the limits shown in Tables 11, 3, 7, and 10, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Common Forms and Tempers—
Flat Drawn Bars—Soft anneal, light anneal, quarter hard, half hard, and hard.
Rods—Soft anneal, light anneal, quarter hard, half hard, hard, and extruded.
Shapes—Quarter hard and extruded.

Typical Uses—This material is intended for use where brass rod that is stronger, tougher, and more corrosion resistant than commercial brass rod is required. Common uses include forgings, water-pump shafts, propeller shafts, studs and nuts, bushings, turnbuckle barrels, adjusting-stud ends, and screw-machine parts.

Common Fabrication Processes—Blanking, drawing, forming and bending, heading and upsetting, hot forging and pressing, hot heading and upsetting, shearing.

Similar Specifications—SAE 73 is similar to ASTM B 21, Alloy A; to ASTM B 124, Alloy 3; and to AMS 4611 and 4612.

SAE 74—Seamless Brass Tubes

Chemical Composition

	74A Muntz Metal	74B Yellow Brass	74C Cartridge Brass	74D Red Brass, 85%
Copper, %	59.0–63.0	65.0–68.0	68.5–71.5	83.0–86.0
Lead, %	0.80 max	0.80 max	0.07 max	0.06 max
Iron, %	0.07 max	0.07 max	0.05 max	0.05 max
Zinc	Remainder	Remainder	Remainder	Remainder

Physical Properties

Tensile Properties—The tensile strength and Rockwell hardness of drawn tubes shall conform with Table 1. Where Rockwell hardness values apply, they can be used as basis for acceptance. In cases of disagreement, the final basis for acceptance shall be the tensile strength.

Annealed Temper Properties—The grain-size requirements for cold-rolled annealed tempers shall conform to Table 2. The Rockwell hardness values are shown for information only.

Expansion Test—A hardened and ground tapered pin, having an included angle of 60 deg, shall be capable of being driven, without rupture of the tube, into one end of annealed tube until

the diameter of tubes ¾ in. and under is expanded 20%, and the diameter of tubes over ¾ in. is expanded 15%.

Appearance—Surface of these tubes shall be clean and smooth, both inside and out.

Dimensional Tolerances—Dimensions of wall thickness and inside and outside diameters shall be within the limits shown in Tables 5 and 12, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Common Forms and Tempers—

74A—Light annealed, drawn general purpose, hard drawn.

74B and **74C**—0.050 mm, 0.025 mm, drawn general purpose, hard drawn.

74D—0.050 mm, 0.025 mm, drawn general purpose, hard drawn, and light drawn.

TABLE 1—*Tensile Strength and Hardness of SAE 74*

GRADE	TEMPER	TENSILE STRENGTH, PSI		ROCKWELL HARDNESS[a]			
				B Scale		30-T Scale	
		Min	Max	Min	Max	Min	Max
A (Muntz Metal)	Drawn (General Purpose)	54,000	—	58	—	55	—
B and C (Yellow Brass and Cartridge Brass)	Drawn (General Purpose)	54,000	—	55	—	53	—
	Hard[b]	66,000	—	75	—	70	—
D (Red Brass, 85%)	Light	44,000	58,000	45	82	43	75
	Drawn (General Purpose)	44,000	—	45	—	43	—
	Hard	57,000	—	70	—	65	—

[a] Rockwell hardness values apply to tubes with an ID of 0.250 in. or over as follows:
B Scale applies to tubes with wall thickness 0.030 in. and over.
30-T Scale applies to tubes with wall thickness 0.012–0.030.
No Rockwells apply to other tubes.
All hardness tests shall be made on inside surface of tube.

[b] These physical properties apply only to tubes with the following range in dimension. For other combinations use physicals of drawn temper.

OD, in.	*Wall Thickness, in.*
up to 1, inclusive	0.020–0.120, inclusive
over 1 to 2, inclusive	0.035–0.180, inclusive
over 2 to 4, inclusive	0.060–0.250, inclusive

TABLE 2—*Grain Size and Hardness of SAE 74*
(*Annealed Tempers*)

ALLOY	TEMPER	GRAIN SIZE, MM		ROCKWELL HARDNESS[a]			
				F Scale		30-T Scale	
		Min	Max	Min	Max	Min	Max
74A	Light Anneal	—[b]	0.035	70	90	33	56
74B and **74C**	Soft Anneal	0.025	0.060	60	75	18	39
	Light Anneal	—[b]	0.035	67	89	28	53
74D	Soft Anneal	0.025	0.060	55	65	8	23
	Light Anneal	—[b]	0.035	60	75	18	39

[a] F Scale applies to tubes 0.020 in. and over in wall thickness. 30-T Scale applies to tubes 0.015 in. and over in wall thickness.

[b] Material must be fully recrystallized.

Typical Uses—Light drawn temper is used only where a tube of some stiffness, but capable of being bent, is needed. Drawn (general purpose) temper is used where requirements for stiffness or ductility are not extreme. Hard temper is used where tubes as strong as possible are needed. SAE 74A and 74D are used for condenser and heat exchanger tubes, and flexible hose. SAE 74B and 74C are general-purpose materials used for water pipe radiator work, and ornamental work.

Common Fabrication Processes—Forming and bending, upsetting, squeezing and swaging, flaring, roll threading, knurling.

Similar Specifications—SAE 74A is similar to ASTM B 135, Alloy 5. SAE 74B is similar to ASTM B 135, Alloy 3. SAE 74C is similar to ASTM B 135, Alloy 2; and to AMS 4555. SAE 74D is similar to ASTM B 135, Alloy 1.

SAE 75—Copper Tubes

Chemical Composition

Copper 99.90% minimum
Material must be deoxidized

Physical Properties

Tensile and Annealed Temper Properties—Physical properties and grain size of tubing shall conform to Table 1. Where Rockwell hardness values apply, they can be used as basis for acceptance. In cases of disagreement, the final basis for acceptance shall be the tensile strength.

TABLE 1—*Tensile, Hardness and Grain Size of SAE 75*

TEMPER	TENSILE STRENGTH, PSI		ROCKWELL HARDNESS[a]				GRAIN SIZE MM.	
			B Scale		30-T Scale			
	Min	Max	Min	Max	Min	Max	Min	Max
Soft Annealed	—	—	—	—	—	—	0.040	—
Light Annealed	—	—	—	—	—	—	—[b]	0.040
Light Drawn	36,000	47,000	20	52	30	60	—	—
Drawn (General Purpose)	36,000	—	20	—	30	—	—	—
Hard Drawn[c]	45,000	—	45	—	55	—	—	—

[a] Rockwell hardness values apply to tubes with an ID of 0.250 in. or over as follows:
B Scale applies to tubes with wall thickness 0.030 in. and over.
30-T Scale applies to tubes with wall thickness 0.015–0.030.
No Rockwells apply to other tubes.
All hardness tests shall be made on inside surface of tube.

[b] Material must be fully recrystallized.

[c] These physical properties apply only to tubes with the following range in dimension. For other combinations use physicals of drawn temper.

OD, in.	*Wall Thickness, in.*
up to 1, inclusive	0.020–0.120, inclusive
over 1 to 2, inclusive	0.035–0.180, inclusive
over 2 to 4, inclusive	0.060–0.250, inclusive

Expansion Test—A hardened and ground taper pin, having an included angle of 60 deg, shall be capable of being driven into one end of the tube until the diameter of tubes ¾ in. and under is expanded 40%, and the diameter of tubes over ¾ in. is expanded 30% without rupture. This test shall be made on annealed tubes only.

Appearance—Surface of these tubes shall be clean and smooth, both inside and outside.

Dimensional Tolerances—Dimensions of wall thickness and inside and outside diameters shall be within the limits shown in

Tables 5 and 12, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Common Forms and Tempers—

Tube—0.050 mm, 0.025 mm, light drawn, drawn general purpose, hard drawn.

Pipe—Hard.

Typical Uses—Light drawn temper is used only where a tube of some stiffness, but capable of being bent, is needed. Drawn (general purpose) temper is used where requirements for stiffness or ductility are not extreme. Hard temper is used when tubes as strong as possible are needed.

Household—Gas lines, heater lines and units, oil burner lines, plumbing pipe and tube, refrigerators.

Industrial—Condenser, evaporator, and heat exchanger tubes; dairy tubes; distiller tubes; pulp and paper lines; steam and water lines; brewery tubes.

Transportation—Gasoline, hydraulic, and oil lines and oil coolers.

Miscellaneous—Rotating bands, gage lines.

Common Fabrication Processes—Flaring, forming and bending, hot forging and pressing, spinning, squeezing and swaging.

Similar Specifications—SAE 75 is similar to ASTM B 75, B 68, and B 88.

SAE 76—Naval Brass Tubes

[The deletion of this specification from the SAE Handbook is being considered. There are no similar specifications.]

Chemical Composition

Copper, %	59.0–62.0
Tin, %	0.50–1.00
Lead, %	0.30 max
Iron, %	0.10 max
Total Other Impurities, %	0.10 max
Zinc	Remainder

Physical Properties

Tensile Properties—The tensile properties of drawn tubing shall conform to Table 1.

TABLE 1—*Tensile Properties of SAE 76*

WALL THICKNESS IN. INCLUSIVE	MINIMUM TENSILE STRENGTH, PSI	MINIMUM YIELD STRENGTH, PSI	MINIMUM ELONGATION, IN 2 IN., %
0–⅛	60,000	24,000	28
⅛–¼	55,000	22,000	32
¼–	50,000	20,000	35

Expanding Test—Annealed tube shall not rupture when a hardened and ground tapered pin, having an included angle of 60 deg, is driven into one end until the diameter is expanded 20% on tubes through ¾ in. and 15% on tubes over ¾ in.

Appearance—Tubes shall be clean, smooth, and free from injurious defects, both inside and out.

Dimensional Tolerances—The average inside and outside diameters of tubing shall not vary from that specified by more than the tolerances specified in Table 12, under the section on Dimensional Tolerances of Wrought Copper Alloys.

SAE 77—Phosphor Bronze Sheet and Strip

Chemical Composition

	SAE 77A	SAE 77C
Tin, %	3.50–5.80	7.00–9.00
Phosphorus, %	0.03–0.35	0.03–0.25
Lead, %	0.05 max	0.05 max
Iron, %	0.10 max	0.10 max
Zinc, %	0.30 max	0.20 max
Antimony, %	0.01 max	0.01 max
Copper, Tin, and Phosphorus, %	99.50 min	99.50 min

Physical Properties

Tensile Properties—The tensile strength of sheet and strip in various tempers shall conform to Tables 1 and 2. The Rockwell

TABLE 1—*Tensile Strength and Hardness of SAE 77A*

TEMPER AND THICKNESS, IN.	TENSILE STRENGTH, PSI		ROCKWELL HARDNESS			
			B Scale		30-T Scale	
	Min	Max	Min	Max	Min	Max
Soft						
(0.040 and over)	40,000	55,000	7	50	—	—
(0.030 and over)			—	—	24	50
(0.020 to 0.040)			0	45	—	—
(0.010 to 0.030)			—	—	16	46
Half Hard						
(0.040 and over)	55,000	70,000	60	81	—	—
(0.030 and over)			—	—	57	73
(0.020 to 0.040)			53	78	—	—
(0.010 to 0.030)			—	—	52	71
Hard						
(0.040 and over)	72,000	87,000	82	90	—	—
(0.030 and over)			—	—	71	77
(0.020 to 0.040)			80	88	—	—
(0.010 to 0.030)			—	—	69	75
Extra Hard						
(0.040 and over)	84,000	98,500	88	94	—	—
(0.030 and over)			—	—	75	80
(0.020 to 0.040)			86	92	—	—
(0.010 to 0.030)			—	—	73	78
Spring						
(0.040 and over)	91,000	105,000	90	96	—	—
(0.030 and over)			—	—	77	81
(0.020 to 0.040)			88	94	—	—
(0.010 to 0.030)			—	—	75	79
Extra Spring						
(0.040 and over)	96,000	109,000	92	97	—	—
(0.030 and over)			—	—	78	82
(0.020 to 0.040)			89	94	—	—
(0.010 to 0.030)			—	—	76	80

TABLE 2—*Tensile Strength and Hardness of SAE 77C*

TEMPER AND THICKNESS, IN.	TENSILE STRENGTH, PSI		ROCKWELL HARDNESS			
			B Scale		30-T Scale	
	Min	Max	Min	Max	Min	Max
Soft						
(0.040 and over)....	53,000	67,000	29	70	—	—
(0.030 and over)....			—	—	38	68
(0.020 to 0.040).....			20	66	—	—
(0.010 to 0.030).....			—	—	27	62
Half Hard						
(0.040 and over)....	69,000	84,000	76	91	—	—
(0.030 and over)....			—	—	67	78
(0.020 to 0.040).....			69	88	—	—
(0.010 to 0.030).....			—	—	63	75
Hard						
(0.040 and over)....	85,000	100,000	91	97	—	—
(0.030 and over)....			—	—	76	81
(0.020 to 0.040).....			89	95	—	—
(0.010 to 0.030).....			—	—	73	80
Extra Hard						
(0.040 and over)....	97,000	111,500	95	100	—	—
(0.030 and over)....			—	—	78	83
(0.020 to 0.040).....			93	98	—	—
(0.010 to 0.030).....			—	—	77	82
Spring						
(0.040 and over)....	105,000	118,500	97	102	—	—
(0.030 and over).			—	—	79	84
(0.020 to 0.040).....			95	100	—	—
(0.010 to 0.030).....			—	—	78	83
Extra Spring						
(0.040 and over)....	109,500	122,000	98	103	—	—
(0.030 and over)....			—	—	80	84
(0.020 to 0.040).....			96	101	—	—
(0.010 to 0.030).....			—	—	79	83

hardness values are shown for information only.

Dimensional Tolerances—Dimensions of thickness, width, straightness, and length shall be within the limits shown in Tables 2, 6, 8, and 9, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Common Forms and Tempers—

Strip—Half hard, hard, extra hard, spring, and extra spring.

Typical Uses—Springs, switch parts, sleeve bushings, clutch discs, diaphragms, fuse clips, fasteners.

Common Fabrication Processes—Blanking, forming and bending, shearing, stamping.

Miscellaneous—Generally speaking, the selection of the alloy and temper depends on the physical requirements of the finished part and the ease with which it can be made. If greatest possible spring characteristics are desired, then the highest temper of Grade C alloy which will form the part should be used. Less severe requirements may permit the use of the less expensive Grade A alloy. More difficult forming operations can be made with Grade C alloy than with the same strength Grade A alloy, thereby gaining strength without sacrificing formability. For example, flat springs with easy bends across the grain can usually be made with Grade A, spring temper. Flat springs with easy bends either across or with the grain can usually be made of Grade C alloy, extra-hard temper. Even though a lower temper is used, higher average physicals are obtained.

Similar Specifications—SAE 77A is similar to ASTM B 103, Alloy A, and to AMS 4510. SAE 77C is similar to ASTM B 103, Alloy C.

SAE 79—Red Brass and Low Brass Sheet and Strip

Chemical Compositions

	79A Red Brass, 85%	79B Low Brass, 80%
Copper, %.....	84.0–86.0	78.5–81.5
Lead, %.....	0.05	0.05
Iron, %.....	0.05	0.05
Zinc.....	Remainder	Remainder

Physical Properties

Tensile Properties—The tensile strength of sheet and strip shall conform to Table 1. Rockwell hardness values are shown for information only.

TABLE 1—*Tensile Strength and Hardness of SAE 79*

GRADE	TEMPER	TENSILE STRENGTH, PSI		ROCKWELL HARDNESS[a]			
				B Scale		30-T Scale	
		Min	Max	Min	Max	Min	Max
79A	¼ Hard	44,000	54,000	33	62	38	58
	½ Hard	51,000	61,000	56	71	54	64
	¾ Hard	57,000	67,000	66	76	60	68
	Hard	63,000	72,000	72	80	65	70
	Extra Hard	72,000	80,000	78	85	69	74
	Spring	78,000	86,000	82	87	72	75
	Extra Spring	82,000	90,000	84	89	73	76
79B	¼ Hard	48,000	58,000	38	65	42	60
	½ Hard	55,000	65,000	59	73	56	66
	¾ Hard	61,000	71,000	69	79	63	70
	Hard	68,000	77,000	76	84	68	73
	Extra Hard	78,000	87,000	83	89	72	76
	Spring	85,000	93,000	87	92	75	78
	Extra Spring	89,000	97,000	88	93	76	79

[a] B Scale applies to metal 0.020-in. thick and over. 30-T scale applies to metal 0.012-in. thick and over.

Annealed Temper Properties—Designations for degree of anneal shall be in terms of average grain diameter in millimeters and shall conform to the limits specified in Table 2. The Rockwell hardness values are shown for information only.

Dimensional Tolerences—Dimensions of thickness, width, straightness, and length shall be within the limits shown in Tables 1, 6, 8, and 9, respectively, under the section on Dimensional Tolerances of Wrought Copper Alloys.

(*Continued on next page.*)

TABLE 2—*Grain Size and Hardness of SAE 79 (Annealed Tempers)*

GRADE	ANNEAL	AVERAGE GRAIN SIZE, MM		ROCKWELL HARDNESS[a]			
				F Scale		30-T Scale	
		Min	Max	Min	Max	Min	Max
79A	0.015	—[b]	0.025	62	79	19	48
	0.025	0.015	0.035	60	72	16	34
	0.035	0.025	0.050	58	66	13	24
	0.050	0.035	0.070	56	63	10	20
	0.070	0.050	0.100	53	60	6	16
79B	0.015	—[b]	0.025	66	83	25	50
	0.025	0.015	0.035	63	77	20	42
	0.035	0.025	0.050	61	72	16	35
	0.050	0.035	0.070	57	67	8	27
	0.070	0.050	0.120	53	64	2	21

[a] F Scale applies to metal 0.020-in. thick and over. 30-T Scale applies to metal 0.015-in. thick and over.
[b] Must be fully recrystallized.

General Data

Common Forms and Tempers—

79A Strip—0.070 mm, 0.050 mm, 0.035 mm, 0.025 mm, 0.015 mm, quarter hard, half hard, extra hard, spring.

79A Sheet—0.050 mm, half hard.

79B Strip—0.070 mm, 0.050 mm, 0.035 mm, 0.025 mm, 0.015 mm, quarter hard, half hard, hard, spring.

Typical Uses—

Architectural—Etching parts, trim, weatherstrip.

Electrical—Conduit, screw shells, sockets.

Hardware—Eyelets, fasteners, fire extinguishers.

Industrial—Pickling crates, radiator cores.

Miscellaneous—Badges, compacts, costume jewelry, dials, lipstick containers, name plates, rouge boxes, tags.

Common Fabrication Processes—Blanking, coining, drawing, etching, forming and bending, piercing and punching, shearing, spinning, squeezing and swaging, stamping.

Similar Specifications—SAE 79A is similar to ASTM B 36, Alloy 3. SAE 79B is similar to ASTM B 36, Alloy 4.

SAE 80—Brass Wire

Chemical Compositions

	80A Cartridge Brass	80B Yellow Brass
Copper, %	68.5–71.5	63.0–68.5
Lead, %	0.07 max	0.10 max
Iron, %	0.05 max	0.05 max
Zinc	Remainder	Remainder

Physical Properties

Tensile Strength—The tensile strength of wire in various tempers shall conform to Table 1.

Annealed Temper Properties—Designations for degree of anneal shall be in terms of average grain diameter in millimeters and shall conform to the limits specified in Table 2.

Bend Test—Brass wire must be capable of being bent through an angle of 180 deg around a pin of the same diameter without breaking.

Dimensional Tolerance—The wire shall not vary from the specified diameter by more than the amounts listed in Table 13, under the section on Dimensional Tolerances of Wrought Copper Alloys.

TABLE 1—*Tensile Strength (Psi) of SAE 80A and 80B*

TEMPER	MIN	MAX
Eighth Hard	50,000	65,000
Quarter Hard	62,000	77,000
Half Hard	79,000	94,000
Three-Quarters Hard	92,000	107,000
Hard	102,000	117,000
Extra Hard	115,000	129,000
Spring	120,000	—

TABLE 2—*Grain Size of SAE 80A and 80B (Annealed Wire)*

ANNEALING DESIGNATION, MM	AVERAGE GRAIN SIZE, MM	
	Min	Max
0.015	—[a]	0.025
0.025	0.015	0.035
0.035	0.025	0.050
0.050	0.035	0.070
0.070	0.050	0.100
0.100	0.070	—

[a] Must be fully recrystallized.

General Data

Common Forms and Tempers—

Wire—0.050 mm, 0.035 mm, 0.025 mm, 0.015 mm, one-eighth hard, quarter hard, extra hard, spring.

Typical Uses—Brass wire is used for springs, locking wire, rivets, screws, and wrapping turnbuckles.

Common Fabrication Processes—Forming and bending, heading and upsetting, squeezing and swaging.

Similar Specifications—SAE 80A is similar to ASTM B 134, Alloy 6. SAE 80B is similar to ASTM B 134, Alloy 7; and to AMS 4712 and 4713.

SAE 81—Phosphor Bronze Wire and Rod

Chemical Composition

Tin, %	3.50–5.80
Phosphorus, %	0.03–0.35
Lead, %	0.05 max
Iron, %	0.10 max
Zinc, %	0.30 max
Copper, Tin, and Phosphorus, %	99.50 min

Physical Properties

Tensile Properties—The tensile properties of hard-drawn wire and rod in spring temper shall conform to Table 1.

Bend Test—Wire shall withstand being bent cold through an angle of 120 deg, without fracture, around a pin with a diameter two times the diameter of the wire.

Dimensional Tolerances—The diameter, or the distance be-

tween parallel surfaces, shall be within the limits shown in Table 13, under the section on Dimensional Tolerances of Wrought Copper Alloys.

TABLE 1—*Tensile Properties of SAE 81*

WIRE DIAMETER, IN.	MINIMUM TENSILE STRENGTH, PSI		MINIMUM ELONGATION IN 2 IN., %
	Coils	Rods	
Through 0.025	145,000	125,000	—
0.026–0.0625	135,000	115,000	—
0.063–0.125	130,000	110,000	—
0.126–0.250	125,000	105,000	3.5[a]
0.251–0.375	120,000	100,000	5.0
0.376–0.500, incl.	105,000	90,000	9.0

[a] Rods only.

General Data

Common Forms and Tempers—

Wire—One-eighth hard to extra hard, spring.

Typical Uses—Springs, switch parts, fasteners, cotter pins.

Common Fabrication Processes—Bending and forming.

Miscellaneous—Spring wire is frequently subject to embrittlement due to aging. This condition is generally difficult to detect by visual means or by the standard mercurous nitrate test. To correct this condition, the wire should be subjected to a stress-relieving anneal of 6 hr at 375 ± 10 F, or its equivalent, immediately prior to use.

Similar Specifications—This alloy is similar to ASTM B 159, Alloy A (wire); to ASTM B 139 (rod); and to AMS 4720.

SAE 83—Annealed Copper Wire

Chemical Composition

The copper shall be of such quality and purity that when drawn and annealed, it shall have the physical properties and electrical characteristics herein required.

Physical Properties

Tensile Properties—The tensile properties of annealed wire shall conform to Table 1.

TABLE 1—*Tensile Properties of SAE 83*

DIAMETER, IN.		MAXIMUM TENSILE STRENGTH, PSI	MINIMUM ELONGATION IN 10 IN., %
Over	To and including		
0.289	0.460	36,000	35
0.102	0.289	37,000	30
0.020	0.102	38,500	25
0.003	0.020	—	20

Finish—Wire shall be untinned and shall be free from all imperfections not consistent with the best commercial practice. Necessary brazes in soft or annealed wire must be made in accordance with the best commercial practice.

Electrical Resistivity—Electrical resistivity shall be determined at a temperature of 20 C (68 F) and it shall not exceed 875.20 ohms per mile-lb (100% electrical conductivity IACS).

Dimensional Tolerances—Wire sizes shall be expressed in decimals and shall conform to the following variations in nominal diameter:

Sizes 0.010 in. and larger, plus and minus 1%.

Sizes under 0.010 in., plus and minus 0.1 mil (0.0001 in.).

General Data

Typical Uses—Copper wire is primarily used for electrical purposes, but it is also used for metal spraying and copper brazing.

Common Fabrication Processes—Heading and upsetting, roll threading and knurling, squeezing and swaging.

Miscellaneous—The International Electro-Technical Commission in 1913 agreed upon the value of 0.15328 ohms per meter-gram at 20 C (68 F) for the resistivity of copper and considers it equivalent to 100% conductivity. Tables for the electrical resistance of conductors are expressed in ohms, not in conductivity units, since ohms are more understandable. In these specifications, the requirements for electrical resistance are stated as the maximum rejection limits of the resistivity, which is 0.15328 ohms per meter-gram.

For the convenience of those who are accustomed to express resistivity in any one of the several more or less common units, the following equivalents have been prepared for the resistivity of copper at 20 C (68 F): Resistivity of 0.15328 ohms per meter-gram is equal to 875.20 ohms per mile-pound, 1.7241 microhms per centimeter-cube, 0.67879 microhms per inch-cube, or 10.371 ohms per mil-foot.

Similar Specifications—SAE 83 is similar to ASTM B 3 and to AMS 4701.

SAE 88—Brass Forging Rod

Chemical Composition

Copper, %	58.0–62.0
Lead, %	1.50–2.50
Iron, %	0.30 max
Zinc	Remainder

Physical Properties

Physical properties on the rod are not ordinarily required.

Tensile Properties of Forgings—Hot pressed forgings made of this alloy should have the following tensile properties:

Tensile Strength, psi	45,000–60,000
Elongation in 2 in., %	25–60

Dimensional Tolerances—The diameter of round sections shall not vary from that specified by more than the tolerance given in Table 14 under the section on Dimensional Tolerances of Wrought Copper Alloys.

General Data

Common Forms and Tempers—Rod and extruded.

Typical Uses—Forgings and pressings of all kinds.

Common Fabrication Processes—Heading and upsetting, hot forging and pressing, hot heading and upsetting, machining.

Similar Specifications—SAE 88 is similar to ASTM B 124, Alloy 2, and to AMS 4614.

(*Continued on next page.*)

Dimensional Tolerances of Wrought Copper Alloys

Dimensional tolerances for materials fabricated from copper and copper-base alloys shall be as specified in Tables 1–14.

TABLE 1[a]—*Thickness Tolerances*[b] *for Sheets and Strips, SAE 70, 71, and 79*

THICKNESS, IN.		WIDTH, IN.						
Over	To and including	Up to 8 inclusive	Over 8 to 14 inclusive	Over 14 to 20 inclusive	Over 20 to 28 inclusive	Over 28 to 36 inclusive	Over 36 to 48 inclusive	Over 48 to 60 inclusive
—	0.004	0.0003	0.0006	—	—	—	—	—
0.004	0.006	0.0004	0.0008	0.0013	—	—	—	—
0.006	0.009	0.0006	0.001	0.0015	—	—	—	—
0.009	0.013	0.0008	0.0013	0.0018	0.0025	0.003	0.0035	0.004
0.013	0.017	0.001	0.0015	0.002	0.0025	0.003	0.0035	0.0045
0.017	0.021	0.0013	0.0018	0.002	0.003	0.0035	0.004	0.005
0.021	0.026	0.0015	0.002	0.0025	0.003	0.0035	0.004	0.005
0.026	0.037	0.002	0.002	0.0025	0.0035	0.004	0.005	0.006
0.037	0.050	0.002	0.0025	0.003	0.004	0.005	0.006	0.007
0.050	0.073	0.0025	0.003	0.0035	0.005	0.006	0.007	0.008
0.073	0 130	0.003	0.0035	0.004	0.006	0.007	0.008	0.010
0.130	0.188	0.0035	0.004	0.0045	0.007	0.008	0.010	0.012

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-1, Table I, Nonrefractory Alloys, April 1, 1948.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.

TABLE 2[a]—*Thickness Tolerances*[b] *for Sheets and Strips, SAE 77*

THICKNESS, IN.		WIDTH, IN.						
Over	To and including	Up to 8 inclusive	Over 8 to 14 inclusive	Over 14 to 20 inclusive	Over 20 to 28 inclusive	Over 28 to 36 inclusive	Over 36 to 48 inclusive	Over 48 to 60 inclusive
—	0.004	0.0004	0.0008	—	—	—	—	—
0.004	0.006	0.0006	0.001	0.0015	—	—	—	—
0.006	0.009	0.0008	0.0013	0.002	—	—	—	—
0.009	0.013	0.001	0.0015	0.0025	—	—	—	—
0.013	0.017	0.0013	0.002	0.0025	—	—	—	—
0.017	0.021	0.0015	0.0025	0.003	—	—	—	—
0.021	0.026	0.002	0.0025	0.003	0.004	0.005	0.006	0.007
0.026	0.037	0.0025	0.003	0.0035	0.005	0.006	0.007	0.008
0.037	0.050	0.003	0.0035	0.004	0.006	0.007	0.008	0.010
0.050	0.073	0.0035	0.004	0.0045	0.007	0.008	0.010	0.012
0.073	0.130	0.004	0.0045	0.005	0.008	0.010	0.012	0.014
0.130	0.188	0.0045	0.005	0.006	0.010	0.012	0.014	0.016

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-1, Table I, Refractory Alloys, April 1, 1948.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.

TABLE 3[a]—*Thickness Tolerances for Drawn Rectangular Bars, SAE 73, Nonrefractory Alloys*

THICKNESS, IN.	WIDTH, IN.					
	Up to ½ inclusive	Over ½ to 1¼ inclusive	Over 1¼ to 2.00 inclusive	Over 2.00 to 4.00 inclusive	Over 4.00 to 8.00 inclusive	Over 8.00 to 12.00 inclusive
Over 0.188 to 0.500 inclusive	0.0035	0.004	0.0045	0.0045	0.006	0.008
Over 0.500 to 1.00 inclusive	—	0.0045	0.005	0.005	0.007	0.009
Over 1.00 to 2.00 inclusive	—	0.005	0.005	0.006	0.008	—
Over 2.00 to 4.00 inclusive	—	—	—	0.30%[b]	—	—

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-4, Table I, Nonrefractory Alloys, April 1, 1948.
[b] Expressed to the nearest 0.001 in.

TABLE 4[a]—*Thickness Tolerances for Drawn Rectangular Bars, SAE 701, Refractory Alloys*

THICKNESS, IN.	WIDTH, IN.					
	Up to ½ inclusive	Over ½ to 1¼ inclusive	Over 1¼ to 2.00 inclusive	Over 2.00 to 4.00 inclusive	Over 4.00 to 8.00 inclusive	Over 8.00 to 12.00 inclusive
Over 0.188 to 0.500 inclusive	0.005	0.005	0.006	0.007	0.009	0.012
Over 0.500 to 1.00 inclusive	—	0.006	0.007	0.008	0.010	0.013
Over 1.00 to 2.00 inclusive	—	0.006	0.007	0.009	0.011	—
Over 2.00 to 4.00 inclusive	—	—	—	0.50%[b]	—	—

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-4, Table I, Refractory Alloys, April 1, 1948.
[b] Expressed to the nearest 0.001 in.

TABLE 5[a]—*Wall Thickness Tolerances*[b] *for Tubing, SAE 74 and 75, Nonrefractory Alloys*

WALL THICKNESS, IN.	OUTSIDE DIAMETER, IN.						
	1/32 to ⅛ inclusive	Overr ⅛ to ⅝ inclusive	Over ⅝ to 1 inclusive	Over 1 to 2 inclusive	Over 2 to 4 inclusive	Over 4 to 7 inclusive	Ove 7 to 10 inclusive
0.380 and over	—	—	—	5%	5%	6%	6%
0.284 up to 0.380	—	—	0.011	0.012	0.014	0.016	0.018
0.220 up to 0.284	—	—	0.009	0.010	0.012	0.014	0.016
0.165 up to 0.220	—	0.007	0.0075	0.008	0.010	0.012	0.014
0.120 up to 0.165	—	0.005	0.006	0.006	0.008	0.010	0.012
0.083 up to 0.120	—	0.004	0.005	0.005	0.007	0.009	0.011
0.058 up to 0.083	—	0.0035	0.004	0.004	0.006	0.008	0.010
0.035 up to 0.058	0.003	0.003	0.0035	0.0035	0.005	0.007	—
0.025 up to 0.035	0.003	0.0025	0.0025	0.003	0.004	—	—
0.018 up to 0.025	0.003	0.002	0.002	0.0025	—	—	—
Under 0.018	0.002	0.001	0.0015	0.002	—	—	—

[a] This table conforms with Copper and Brass Research Association Standards, Tube, page Tube-1, Table I, July 20, 1949.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.

TABLE 6a[a]—*Width Tolerances*[b] *for Sheets and Strips, SAE 70, 71, 77, and 79, Slit Metal and Slit Metal with Rolled Edges*

WIDTH, IN.	THICKNESS, IN.	
	0.004 to 0.032 inclusive	Over 0.032 to 0.187 inclusive
Up to 2 inclusive	0.005	0.010
Over 2 to 8 inclusive	0.008	0.013
Over 8 to 14 inclusive	1/64	1/64
Over 14 to 20 inclusive	1/64	1/64

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-2, Table III, Dec. 7, 1949.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.

TABLE 6b[a]—*Width Tolerances*[b] *for Sheets and Strips, SAE 70, 71, 77, and 79, Square Sheared Metal in All Lengths Up Through 120 Inches*

WIDTH, IN.	THICKNESS, IN.		
	Up to 1/16 inclusive	Over 1/16 to 1/8 inclusive	Over 1/8
Up to 20 inclusive	1/32	3/64	1/16
Over 20 to 36 inclusive	3/64	3/64	1/16
Over 36 to 60 inclusive	1/16	1/16	1/16

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-2-A, Table II, Dec. 7, 1949.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.

TABLE 6c[a]—*Width Tolerances*[b] *for Sheets and Strips, SAE 70, 71, 77, and 79, Rolled Edge Metal (Not Previously Slit)*[c]

WIDTH, IN.	WIDTH TOLERANCES, IN.	
	Nonrefractory alloys SAE 70, 71, 79	Refractory alloy SAE 77
Up to 0.050 inclusive	0.0013	0.0015
Over 0.050 to 0.090 inclusive	0.0015	0.002
Over 0.090 to 0.130 inclusive	0.002	0.003
Over 0.130 to 0.188 inclusive	0.003	0.004
Over 0.188 to 0.500 inclusive	0.0035	0.005
Over 0.500 to 1.25 inclusive	0.005	0.007
Over 1.25 to 2.00 inclusive	0.008	0.010
Over 2.00 to 4.00 inclusive	0.012	0.015
Over 4.00 to 12.00 inclusive	0.30%[d]	0.50%[d]

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-4, Table II, April 1, 1948.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.
[c] Available only in products produced from round wire, wire bars, or extruded shapes.
[d] Expressed to nearest 0.001 in.

TABLE 6d[a]—*Width Tolerances*[b] *for Sheets and Strips, SAE 70, 71, 77, and 79, Sawed Metal*

WIDTH, IN.	FOR LENGTHS UP TO 10 FT		FOR LENGTHS OVER 10 FT	
	For thicknesses up to 1½ in. inclusive	For thicknesses over 1½ in.	For thicknesses up to 1½ in. inclusive	For thicknesses over 1½ in.
Up to 12 in. wide, inclusive	1/32	1/16	3/64	1/16
Over 12 in. wide to 120 in., inclusive	1/16	1/16	1/16	1/16

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-2-A, Table III, Dec. 7, 1949.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.

TABLE 7[a]—*Width Tolerances for Rectangular Bars (Not Including Squares*[b]*), SAE 701 and 73*

WIDTH, IN.	NON REFRACTORY ALLOY SAE 73	REFRACTORY ALLOY SAE 701
Up to 0.050 inclusive	0.0013	0.0015
Over 0.050 to 0.090 inclusive	0.0015	0.002
Over 0.090 to 0.130 inclusive	0.002	0.003
Over 0.130 to 0.188 inclusive	0.003	0.004
Over 0.188 to 0.500 inclusive	0.0035	0.005
Over 0.500 to 1.25 inclusive	0.005	0.007
Over 1.25 to 2.00 inclusive	0.008	0.010
Over 2.00 to 4.00 inclusive	0.012	0.015
Over 4.00 to 12.00 inclusive	0.30%[c]	0.50%[c]

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-4, Table II, April 1, 1949.
[b] For squares, use thickness tolerances of Tables 3 and 4.
[c] Expressed to the nearest 0.001 in.

TABLE 8a[a]—*Straightness Tolerances in Inches, SAE 70, 71, 77, and 79; Maximum Edgewise Curvature (Depth of Arc) in Any 72-In. Portion of Total Length*

	WIDTH, IN.				
	½ in. and under	Over ½ in. to 1 in. inclusive	Over 1 in. to 2 in. inclusive	Over 2 in. to 5 in. inclusive	Over 5 in.
Slit Metal					
As slit, shipped in rolls	3	1¼	¾	⅝	½
With rolled edges or as straightened, shipped flat or in rolls	½	½	½	½	½
Rolled Edge Metal (Not Previously Slit)					
Shipped in straight lengths, in rolls, or on bucks	½	½	½	½	½
Shipped on reels or in stagger wound rolls[b]	—	—	—	—	—

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-3, Table I, Dec. 7, 1949.
[b] No straightness tolerances established.

TABLE 8b[a]—*Straightness Tolerances, SAE 70, 71, 77, and 79; Square Sheared Metal Not Over 120 Inches in Length*

THICKNESS, IN.	TOLERANCES, IN.	
	Up to 10 in., inclusive, in width	Over 10 in. in width
⅛ and under	1/16	1/32
Over ⅛ to 3/16, inclusive	⅛	3/64
Over 3/16	⅛	1/16

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-3, Table II, Dec. 7, 1949.

TABLE 8c[a]—*Straightness Tolerances, SAE 70, 71, 77, and 79; Sawed Metal Not Over 144 Inches in Length*

WIDTH, IN.	TOLERANCES, IN.
3 and under	1/16
Over 3	3/64

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-3, Table III, Dec. 7, 1949.

TABLE 9a[a]—*Length Tolerances in Inches, SAE 70, 71, 77, and 79; Flat Straight Lengths and Only Full-Length Pieces*

LENGTHS	TOLERANCES
Specific lengths,	
up to 10 ft inclusive	1/4
over 10 ft to 20 ft inclusive	1/2
Specific lengths with ends	1
Stock lengths with or without ends	1[b]

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-2, Table I, Dec. 7, 1949.
[b] Because stock lengths are cut and placed in stock in advance of orders, departure from this tolerance is not practicable.

TABLE 9b[a]—*Length Tolerances in Inches, SAE 70, 71, 77, and 79; Square Sheared Metal*

LENGTH AND WIDTH, IN.	FOR THICKNESSES, IN.		
	Up to 1/16 inclusive	Over 1/16 to 1/8	Over 1/8
Up to 20 inclusive	1/32	3/64	1/16
Over 20 to 36 inclusive	3/64	3/64	1/16
Over 36 to 120 inclusive	1/16	1/16	1/16

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-2-A, Table I, Dec. 7, 1949.

TABLE 10[a]—*Length Tolerances for Rods, Bars, and Shapes, SAE 701, 72, and 73*

LENGTHS	TOLERANCE, IN. (ALL PLUS)[b]
Specific lengths	3/8
Specific lengths with ends	1
Stock lengths with or without ends	1[c]
Rods	None established

[a] This table conforms with Copper and Brass Research Association Standards, Flat Products, page FP-5, Table I, May 7, 1948.
[b] If all minus tolerances are desired, use the same values; if tolerances are desired plus and minus, halve the values given.
[c] Because stock lengths are cut and placed in stock in advance of orders, departure from this tolerance is not practicable.

TABLE 11[a]—*Diameter Tolerances[b] for Rods, Bars, and Shapes, SAE 701, 72, and 73*

DIAMETER (OR DISTANCE BETWEEN PARALLEL SURFACES), IN.	NONREFRACTORY ALLOYS SAE 72 and 73		REFRACTORY ALLOYS SAE 701	
	Round	Hexagonal Octagonal	Round	Hexagonal Octagonal
Up to 0.150 inclusive	0.0013	0.0025	0.002	—
Over 0.150 to 0.500 inclusive	0.0015	0.003	0.002	0.004
Over 0.500 to 1.00 inclusive	0.002	0.004	0.003	0.005
Over 1.00 to 2.00 inclusive	0.0025	0.005	0.004	0.006
Over 2.00	0.15%[c]	0.30%[c]	0.20%[c]	0.40%[c]

[a] This table conforms with Copper and Brass Research Association Standards, Rod, page Rod-1, Table I, Feb. 26, 1948.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.
[c] Expressed to the nearest 0.001 in.

TABLE 12[a]—*Average Diameter[b] Tolerances for Tubing, SAE 74, 75, and 76*

SPECIFIED DIAMETER, IN.	DIAMETER TOLERANCE APPLIES TO	TOLERANCE,[c] IN.	
		Nonrefractory alloys SAE 74 and 75	Refractory alloy SAE 76
Up to 1/8 inclusive	Inside	0.002	0.003
Up to 1/8 inclusive	Outside	0.002	0.0025
Over 1/8 to 5/8 inclusive	Inside or Outside	0.002	0.0025
Over 5/8 to 1 inclusive	Inside or Outside	0.0025	0.003
Over 1 to 2 inclusive	Inside or Outside	0.003	0.004
Over 2 to 3 inclusive	Inside or Outside	0.004	0.005
Over 3 to 4 inclusive	Inside or Outside	0.005	0.006
Over 4 to 5 inclusive	Inside or Outside	0.006	0.008
Over 5 to 6 inclusive	Inside or Outside	0.007	0.009
Over 6 to 8 inclusive	Inside or Outside	0.008	0.010
Over 8 to 10 inclusive	Inside or Outside	0.010	0.013

[a] This table conforms with Copper and Brass Research Association Standards, Tube, page Tube-1, Table III, July 20, 1949.
[b] The average diameter of a tube is the average of the maximum and minimum outside diameters or of the maximum and minimum inside diameters, as determined at any one cross-section of the tube.
[c] All tolerances plus and minus.

TABLE 13[a]—*Diameter Tolerances[b] for Wire, SAE 80 and 81*

DIAMETER (OR DISTANCE BETWEEN PARALLEL SURFACES), IN.	NONREFRACTORY ALLOY SAE 80		REFRACTORY ALLOY SAE 81	
	Round	Hexagonal Octagonal	Round	Hexagonal Octagonal
Up to 0.010 inclusive	0.0001	—	0.0002	—
Over 0.010 to 0.020 inclusive	0.0002	—	0.0003	—
Over 0.020 to 0.030 inclusive	0.0003	—	0.0005	—
Over 0.030 to 0.040 inclusive	0.0004	0.0008	0.0007	0.002
Over 0.040 to 0.050 inclusive	0.0005	0.0010	0.0008	0.003
Over 0.050 to 0.060 inclusive	0.0006	0.0012	0.0010	0.003
Over 0.060 to 0.080 inclusive	0.0008	0.0016	0.0015	0.004
Over 0.080 to 0.150 inclusive	0.0010	0.002	0.002	0.004
Over 0.150 to 0.500 inclusive	0.0015	0.003	0.002	0.004
Over 0.500 to 0.750 inclusive	0.002	0.004	0.003	0.005

[a] This table conforms with Copper and Brass Research Association Standards, Rod, page Rod-1, Table IV, Feb. 26, 1948.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.

TABLE 14[a]—*Diameter Tolerances[b] for Brass Forging Rod, SAE 88*

DIAMETER, IN.		TOLERANCES, IN. ROUND, SQUARE, RECTANGULAR, HEXAGONAL, OCTAGONAL
Over	To and including	
0	1.00	0.010
1.00	2.00	0.015
2.00	3.00	0.025
3.00	3.50	0.035
3.50	4.00	0.060

[a] This table conforms with Copper and Brass Research Association Standards, Rod, page Rod-2, Table I, Nonrefractory Alloys, Aug. 26, 1948.
[b] The tolerances given are plus and minus; if tolerances are desired all plus or all minus, double the values given.

Alumium Alloys

SAE General Information

Report of Nonferrous Metals Division approved January 1934 and last revised by Nonferrous Metals Technical Committee January 1950.

Sources of Aluminum—Although compounds of aluminum form a part of every clay deposit the world over, the principal commercial ore is bauxite, composed primarily of hydrated aluminum oxide with the oxides of iron, silicon, and titanium as impurities. Workable deposits of this ore are located in many parts of the world, but the ones used as the primary sources of raw material for the aluminum industry of this country are in Arkansas and Surinam. Of these, the South American beds hold the largest reserves.

Aluminum, unlike most other common metals, cannot be won from its ores by simple and inexpensive smelting operations. The bauxite must first be treated chemically in order to secure aluminum oxide of high purity; then this oxide must be reduced to metal by an electrolytic process. Several different processes are used for producing pure alumina from the ore, but the most common one used in this country is the Bayer process. The electrolytic reduction process consumes large amounts of electric power, and to be economical, requires that reduction operations be located near sources of cheap power. Although aluminum of a purity up to about 99.9% is produced on a limited commercial scale in the usual reduction pots, the normal *pure* aluminum of commerce ranges in purity from about 99.0 to 99.5%. The usual impurities in the commercially pure metal are iron and silicon, although small amounts of copper and spectrographic traces of a number of other elements also may be present.

Properties—Commercially pure aluminum is a face-centered cubic metal with a specific gravity of about 2.71 (0.098 lb per cu in.), a thermal conductivity of about 0.52 cgs units (at 25 C), and a melting point of approximately 1215 F. Its coefficient of thermal expansion (approximately 0.000013 per F) is about twice that of steel or cast iron and about one third greater than that of copper or brass. The electrical conductivity of *pure* aluminum is about 61% of the International Annealed Copper Standard (35.38×10^4 mhos per cm cubed at 20 C). In the form of sand-cast test bars, the commercially pure metal has a tensile strength of about 14,000 psi and an elongation of about 30% in 2 in., while sheet in the annealed temper has a tensile strength of the order of 13,000 psi and an elongation of about 45% in 2 in. The modulus of elasticity, for all practical purposes, is 10,000,000 psi. The commercially pure metal is highly resistant to atmospheric corrosion and to attack by many chemicals, with the notable exception of strong alkalis. Because it is so high in the electrochemical series, however, it is subject to galvanic attack if coupled with metals such as the copper alloys in the presence of a good electrolyte.

Alloying Elements—Additions of alloying elements usually increase the specific gravity (silicon and magnesium lower it), decrease the electrical and thermal conductivity and the melting point, increase the strength, and have a rather slight effect on the coefficient of thermal expansion and the modulus of elasticity. Some alloying elements, alone or in combination, produce alloys susceptible to heat-treatment. The effect of alloying elements on the resistance to corrosion varies somewhat, but alloying additions generally lower the resistance to corrosion of the pure aluminum. The alloying elements commonly used in this country are copper, silicon, magnesium, manganese, zinc, and nickel, with the three first named by far the most common.

Working and Heat-Treating—Aluminum and its commercial alloys, being rather ductile materials, can be hot or cold worked into most of the common manufactured forms. The commercially pure metal and some of the alloys are not heat-treatable compositions, and attain their strengths either by virtue of the alloy content or because of strain hardening resulting from cold work. The strength of many of the alloys, however, can be further increased by suitable heat-treatments.

The response of an aluminum alloy to heat-treatment depends on the presence of one or more alloying elements substantially more soluble in aluminum at temperatures of about 900 to 1000 F than at room temperature. By heating the material for a sufficient time at the high temperature, the alloying elements are substantially dissolved by the aluminum; and by quenching rapidly from the solution treating temperature, the elements are retained in solution. Longer heating times are required for castings than for wrought products, and for heavy as compared to light sections. The quench should be as rapid as possible in order to secure the highest resistance to corrosion, although castings cannot be too drastically quenched for they may crack or develop such high internal stresses that excessive distortion during machining is encountered.

Certain of the heat-treatable alloys, notably the so-called duralumin type alloys, age harden considerably at room temperature within a few days after quenching; the others, although they harden slowly at room temperature, must be heated to about 300 F for a few hours to attain their maximum strengths. Even the alloys which age harden substantially at room temperature can be made to develop even greater strength by an elevated temperature treatment. It is generally agreed that the age hardening results from the precipitation of alloying elements or compounds from the supersaturated solid solution in the form of minute particles. It is believed that these particles, because of their critical size and location in the crystal structure, impede or prevent slip and thus increase the strength of the metal. Because of the phenomenon involved, these aging treatments often are referred to as precipitation treatments. In this connection, it is interesting to note that the better workability of the as-quenched material can be retained in those alloys which age at room temperature by the simple expedient of storing the quenched material at about 0 F.

The effects of either cold work or heat-treatment on the strength and workability of the materials can be removed by annealing at temperatures of about 600 to 800 F, depending on the alloy and temper. It must be remembered, however, that the strength of a nonheat-treatable alloy can only be regained, after annealing, by the introduction of additional cold work.

Temper Designations—The standards in the past have employed rather arbitrary temper designations for aluminum casting alloys, while generally following commercial practice in the temper designations for wrought alloys. Since the industry has now adopted a uniform terminology, these new commercial designations are being used in the standards. For a while, the temper

designations formerly used in the standards will be included, in parentheses, after the new designation to simplify conversions and to minimize confusion. A brief description of the new designations is given below; more detailed information can be secured from the manufacturers.

Wrought aluminum alloys are of two types: those strengthened by cold work (Type 1), and those which respond to heat-treatment (Type 2). With minor exceptions all wrought alloys of both types are commercially available in the annealed (O) and the as-fabricated (F) conditions.

The casting alloys, too, are similarly divided into two types: the Type 1 alloys either do not respond to heat-treatment or, for practical purposes, are not used in a heat-treated temper; while the Type 2 alloys are those in which heat-treatment is the usual practice. Annealing is not usually considered as a heat-treatment, but it is a treatment which can be applied to either type of casting alloy.

In the Type 1 wrought alloys, the temper of material cold worked to the maximum practicable degree has, in the past, been called hard (or full hard) and designated by the letter H. The standard tempers intermediate between the annealed and hard have been called quarter hard, half hard, and three-quarters hard and designated ¼H, ½H, or ¾H. While it generally has been considered that these tempers were produced simply by cold reduction of the cross-sectional area, this has not literally been the practice for alloys like SAE 201, and is not the only possible method of producing some intermediate tempers of SAE 25 and 29. The fabricating practices for SAE 201, for example, usually include a final thermal treatment to stabilize the mechanical properties; and it is possible with SAE 25 and 29, to produce an intermediate temper by partially annealing a highly cold-worked material. The old designations did not recognize these variations, but the new system provides for them, even though the partially annealed product is not in regular commercial use.

The temper designation for the wrought materials which have been only cold worked consists of the symbol H1 and a number indicating the degree of cold working. The standard tempers are H12 (¼H), H14 (½H), H16 (¾H), and H18 (H) and are the ones normally applicable to SAE 25 and 29 sheet, tubing, and wire. For material brought to the desired level of strength by partial annealing, the designation consists of the symbol H2 and a number indicating the level of strength. The resulting designations thus become H22, H24, H26, and H28.

When the material is cold worked to the desired level of strength and then stabilized, as is the usual practice for SAE 20 and 201, the temper designation consists of the symbol H3 and the temper number. Thus, the standard commercial tempers for SAE 20 and 201 are H32 (¼H), H34 (½H), H36 (¾H), and H38 (H).

While the heat-treatable wrought alloys (Type 2) can be produced in the cold-worked tempers of the H1 series, the properties of the cold worked materials are not commercially attractive; and the tempers are, therefore, not considered standard.

In planning the new nomenclature system, provision has been made for a considerable variety of tempers which, at least theoretically, can be produced in wrought alloys by various combinations of heat-treatments and cold working, and in castings by combinations of heat-treatments. In many alloys, only a few of these possible tempers have commercial significance. In brief, however, the temper designations for Type 2 alloys are as follows:

O —Annealed (wrought products only)
T2 —Annealed (castings only)
T3 —Solution heat-treated and then cold worked
T4 —Solution heat-treated
T5 —Artificially aged only
T6 —Solution heat-treated and then artificially aged
T7 —Solution heat-treated and then stabilized
T8 —Solution heat-treated, cold worked, and then artificially aged
T9 —Solution heat-treated, artificially aged, and then cold worked
T10—Artificially aged and then cold worked
F —As fabricated

Since O has long been used as the temper designation for annealed wrought alloys and T2 as the designation for annealed castings, both symbols were retained in the new system. In addition to the designations described above, the system provides that "W" shall be used to denote the temper of material which has been solution heat-treated but which does not have stable properties (that is, continuously age-hardens at room temperature for some time). As far as these standards are concerned, the designation "W" is of academic interest.

One of the basic principles applying to the use of these temper designations is that a given symbol, when applied to a specific alloy and product, denotes a definite set of specification physical properties as well as a given type of heat-treating practice. The symbol does *not* necessarily definite the time and temperature of the thermal treatments nor, where working is part of the cycle, the specific amount of cold work; the details of the practice may be varied as desired or convenient if the end result, as expressed by specified minimum mechanical properties, is unchanged. On the other hand, if a variation in the details of the practice, without changing the *type* of practice, produces a change in the acceptable specification mechanical properties, a modification of the temper designation is in order. For example, a material solution heat-treated and artificially aged by one practice may develop consistently higher strength than the same material heat-treated and aged by a different practice, and both levels of strength may be commercially useful. In such a case, the one temper may be designated T6 and the other T61. Normally, the simple designation (T6) will be used for the temper first commercialized, and the more complex symbols employed for subsequently developed (or limited purpose) tempers. Multi-digit symbols are more com-

TABLE 1—*Old and New Temper Designations for Aluminum Alloys*

OLD DESIGNATION	NEW DESIGNATIONS[a]		
	Strain hardened only[b]	Strain hardened and then partially annealed[c]	Strain hardened and then stabilized[d]
¼H (¼ hard)	H12	H22	H32
½H (½ hard)	H14	H24	H34
¾H (¾ hard)	H16	H26	H36
H (hard)	H18	H28	H38
F (as-fabricated)	F	—	—

[a] The temper designation for annealed material of any alloy is O.
[b] Standard tempers for SAE 25 and 29.
[c] Not commercially standard.
[d] Standard tempers for SAE 20 and 201; these alloys also available in F temper.

mon for castings than for wrought products; but, in both classes of product, the first number after the T defines the *type* of treatment and subsequent numbers serve only to define the specific properties to be expected.

Welding and Brazing—Aluminum and most of its alloys can be welded by the common fusion and electrical-resistance methods, although experience is required to attain the best results. The facility with which the alloys can be welded depends, to a considerable extent, upon the composition. Commercially practical torch, dip, and furnace brazing procedures are available and are being used to an increasing extent. Welding frequently is used in the foundry in the repair of minor casting defects, such as small cracks and sand holes. In planning welded or brazed assemblies, however, it must be recognized that the temperatures reached during the joining operations are above the annealing temperature. Fusion welding of heat-treated materials is not generally recommended unless reheat-treatment is practicable, because the heat of welding not only affects the strength, but also may reduce the resistance to corrosion.

Forming—Aluminum and its alloys can be formed hot or cold with considerable ease, although the bend radii for cold forming and the allowance for spring-back must be increased as the strength of the material increases. For severe forming, very deep drawing, or spinning, the annealed (O) temper usually is employed; while for the less drastic operations, the intermediate, cold-worked temper (H12, H22, or H32; or H14, H24, or H34), or the as-quenched (T3 or T4) temper usually is selected. The full hard (H18, H28, or H38) or the heat-treated and aged (T6) tempers are not usually used where more than slight forming is required. Heat-treatable alloys, however, can often be formed in the annealed or the as-quenched tempers and subsequently heat-treated to the desired temper.

Machining—The aluminum alloys can generally be machined easily, if suitable practices and proper tools are used. In fact, considerable tonnages of aluminum-alloy rods and bars are regularly used for making screw-machine products.

Finishing and Coating—The aluminum alloys can be given a wide variety of mechanical, chemical, electrochemical, or paint finishes. The more common mechanical finishes include sand or grit blasting, scratch brushing, and buffing, while the chemical finishes may be a simple dip coating or an etching treatment. The possibility of generating an explosive mixture of finely powdered metal and air should be borne in mind in connection with mechanical finishing operations. Paint coatings may be either a clear lacquer or a pigmented coating and may be applied to secure either decoration or protection, or both. Electroplating, although not extensively practiced in the past, is now gaining increased commercial use.

Anodic coatings can be produced to provide good protection against corrosion and are also good bases for subsequent paint coatings. These coatings can be dyed, and they make possible a variety of colored surfaces suitable for many decorative applications. Their hard, wear-resisting surface is made use of in many applications.

To simplify presentation of information about the aluminum alloys, the materials have been grouped under the general headings of casting alloys and wrought alloys. Generally speaking, a given composition is not used commercially for both wrought and cast products, and the casting alloys usually contain a somewhat greater total alloy content than the wrought alloys. When yield strength is specified, it is that stress at which the stress-strain curve deviates 0.2% from the modulus line.

Aluminum Casting Alloys

The SAE Standard on Aluminum Casting Alloys covers a wide range of castings for general and special applications but does not include all of the alloys in commercial use. If those listed do not have the required characteristics, it is recommended that the manufacturers of aluminum castings be consulted.

There are two general types of cast-aluminum alloys which, for convenience, are called Types 1 and 2 in the Standard. The Type 1 alloys normally are used in the as-cast condition (F) but may be annealed (T2) to relieve casting stresses, or to reduce the possibility of distortion during machining. The Type 2 alloys usually are used in a heat-treated condition because of the increased strengths resulting from the heat-treatment. These treatments generally consist of a high-temperature solution treatment, followed by quenching in water, and a low-temperature aging treatment (T6).

By aging the solution-treated castings at higher temperatures (T7), a product having more stable properties in service at elevated temperatures and one less likely to distort during machining is obtained. Occasionally, the aging treatment is omitted and the castings are used in the quenched condition (T4); at other times (especially in castings to be used at elevated temperatures) the solution treatment is omitted and the castings are merely stabilized or aged (T5). Various combinations of properties can be secured by adjusting the thermal treatments, but only the commonly-used conditions form a part of the SAE Standard.

The physical properties shown in the Standard are the values that should be obtained from standard test specimens separately cast under conditions that duplicate as closely as possible the conditions of solidification of the casting, and tested without machining except to adapt the ends to the grips of the testing equipment. The properties for sand-casting alloys were obtained from ½-in. diameter standard test bars cast without chills in green sand molds, and the properties for the permanent-mold alloys were obtained from test bars cast in a metal mold. The properties given for die-casting alloys were obtained from die-cast test bars similar to the one shown in ASTM E 8.

The properties obtained from test specimens machined from castings will vary, depending upon the location from which the bar is taken. Specimens taken from thin sections may have properties higher than those of separately cast test bars, while specimens taken from heavy sections or from locations near gates or risers may show lower properties. These relations are not peculiar to aluminum-alloy castings but are the same in the castings of other metals. In general, when test bars machined from a casting are used as the basis for acceptance or rejection, it is a standard requirement that three or more bars, taken to represent the thickest, the thinnest, and an average cross-section, shall have an average tensile strength not less than 75% of the specified tensile strength and an elongation not less than 25% of the specified elongation. The separately cast test specimen serves as a control of the metal quality, and in the case of heat-treated alloys, serves also as a control of the heat-treatment process, since such test bars must be heat-treated with the castings that they represent. Factors of safety used in design cover the variations of commercial castings from the properties specified for the

alloy, which are based on tests of separately cast test specimens.

The choice among the alloys depends upon the service requirements of the casting and in some cases upon the ability to produce the desired part. Some of the alloys are adapted for use at elevated temperatures, some are particularly resistant to corrosion under severe conditions of exposure, and some are more easily cast into complicated shapes that require pressure tightness. Others may be chosen primarily because of their lower cost where physical property requirements are of secondary importance. Specifications for the individual alloys indicate typical applications which will assist in the choice of alloy for any purpose.

The physical properties and dimensional tolerances required, the number of castings to be made, the surface finish desired, and the amount of machining necessary are factors to be considered in deciding among sand, permanent-mold, and die castings. Sand castings usually are used when the number required is small, when a smooth surface is not required, or can be secured economically by machining, and when close tolerances on as-cast dimensions are not essential. Permanent-mold castings usually have a smoother finish and may thus require less machining, can be cast to closer tolerances, and, for the same chemistry, generally have slightly higher properties. Die castings can be held to much closer tolerances than either sand or permanent-mold castings. In addition, practically all holes can be included, and the castings have a smooth surface requiring a minimum of preparation for final finishings. The uniformity of the castings makes for simpler tooling and lower costs of subsequent machining operations. The savings resulting from these lower machining and finishing costs are the determining factor in deciding what volume is necessary to justify the cost of the die. Producers of castings should also be consulted to insure the selection of the most suitable and economical casting method and the alloy best suited for conditions under which the casting will be used.

In the design of patterns for the production of aluminum-alloy sand castings, a shrinkage of 0.156 (5/32) in. per ft is usually al-

SAE Number	USUAL FORM	GENERAL DATA
300	Permanent Mold Castings	Pistons primarily.
304	Die Castings	Good casting characteristics and resistance to corrosion.
305	Die Castings	Highly resistant to corrosion; excellent casting characteristics; used for complicated castings of thin section.
306	Die Castings	Good casting characteristics and fair resistance to corrosion; not especially suited for thin sections; limited to cold-chamber machines.
307	Die Castings	Similar to SAE 306 but casts less easily.
308	Die Castings	Same as SAE 306 but suitable for use in either cold-chamber or gooseneck machines.
309	Die Castings	Excellent casting characteristics; suited for use in thin-walled or intricate castings produced in cold-chamber casting machine; corrosion resistance high.
310	Sand Castings	General-purpose structural castings developing strengths equivalent to SAE 38 without requiring heat treatment.
320	Sand Castings	Moderate strength; high resistance to corrosion.
321	Permanent-Mold Castings	Pistons, low expansion.
322	Sand and Permanent-Mold Castings	General use where high strength and pressure tightness is required, such as pump bodies and liquid-cooled cylinder heads.
323	Sand and Permanent-Mold Castings	Alternate for SAE 38 in intricate castings.
324	Sand Castings	High strength and ductility; structural use; requires special foundry practice.
326	Sand and Permanent-Mold Castings	General-purpose alloy.
327	Sand Castings	Similar to SAE 322 and 323.
328	Permanent-Mold Castings	Pistons.
329	Sand Castings	General-purpose, low-cost alloy; good foundry characteristics; good machinability; similar to SAE 326
33	Sand and Permanent-Mold Castings	General-purpose alloy with fair strength and resistance to corrosion; often used for oil pans, crankcases, camshaft housings, and other parts not highly stressed.
330	Permanent-Mold Castings	Moderate strength, general-purpose alloy with excellent foundry characteristics; fair resistance to corrosion; good machinability.
331	Permanent-Mold Castings	Very good foundry characteristics; fair resistance to corrosion; good machinability.
332	Permanent-Mold Castings	Primarily intended for automotive use in pistons.
34	Sand and Permanent-Mold Castings	Primarily a piston alloy, but also used for aircooled cylinder heads and valve tappet guides.
35	Sand and Permanent-Mold Castings	Used for intricate castings having thin sections; good resistance to corrosion; fair strength but good ductility.
38	Sand Castings	General structural castings requiring high strength and shock resistance.
380	Permanent-Mold Castings	Modification of SAE 38 suitable for use in permanent molds.
39	Sand and Permanent-Mold Castings	Used primarily for aircooled cylinder heads, but also used for pistons in high-performance gasoline engines.

lowed, although this value may vary slightly depending upon the form and size of the casting. The producer of castings should be consulted concerning the design of the pattern so that the best results may be obtained with the alloy that is to be used.

Wrought Aluminum Alloys

The SAE Standard on Wrought Aluminum Alloys covers wrought materials with a considerable range of properties and other characteristics but does not include all of the commercially available materials. If none of the SAE materials provides the characteristics required by a particular application, users may find it helpful to consult with the suppliers of aluminum-alloy products.

SAE Number	USUAL FORM	TYPICAL USES
20	Sheet and tube	Miscellaneous body parts, fuel and brake lines.
201	Sheet, plate, bar, wire, and tubing	Truck and bus panels and roof sheets, engine cowling, fuel and oil lines.
24	Most wrought forms	High-strength structural applications.
240	Sheet and plate	High-strength structural applications where high resistance to corrosion is required.
25	Most wrought forms	Where forming and resistance to corrosion is required and low stresses are involved.
26	Rods, bars, wire, and rolled shapes	Screw-machine products and ordinary structural applications.
260	Forgings, extrusions and rolled shapes, rods, and bars	Highly stressed forgings; alternate for SAE 24 and 26 for rods, bars, and shapes.
270	Forgings	Forged pistons.
280	Forgings and impact extrusions	Complicated forgings of moderate strength.
281	Sheet, plate, shapes, tubing, rods, bars, wire, and rivets	Combines good forming characteristics with high resistance to corrosion and moderately high strength.
282	Extrusions and rivets	Largely supplanted by SAE 281 for most applications.
29	Most wrought forms	Higher strength and slightly less workable than SAE 25; similar uses.
290	Forgings	Forged pistons.

The wrought aluminum alloys also are of two types: those designated as Type 1 are alloys in which the harder tempers are the result of strain hardening produced by cold work, while those designated as Type 2 are alloys in which the higher strengths are produced by heat-treatment processes.

Tempers, Type 1 Alloys—The Type 1 alloys generally are available in the soft (or O) temper, several intermediate tempers, and the hard temper. The hard temper results from cold working the material to the maximum reduction in cross-sectional area which is commercially practicable. The intermediate tempers are the result of applying only sufficient cold work, after the last process anneal, to obtain the desired tensile strength. In the case of alloys SAE 20 and 201, the cold working usually is followed by a low-temperature stabilizing treatment to preclude small changes in strength during subsequent service. The temper designation indicates whether the material has been brought to the final level of strength by cold work only or by cold work followed by stabilizing. In the former case, the designation takes the form H1X and, in the latter, the form H3X.

While there is some overlapping of the tensile-strength ranges for the different tempers, each temper possesses fairly definite forming characteristics. In general, the hardest temper that will withstand the required fabricating operations is chosen.

It is not commercially practicable to produce heavy plates in the harder tempers, because of the large amount of cold rolling necessary to develop the required properties. It is therefore customary to supply plates hot finished to final thickness from hot ingots. There is a certain amount of cooling of the metal during the rolling operation with the result that the metal is strain hardened to some extent, the amount being greater the thinner the finished plate. It is more economical to obtain higher strengths in plates by the choice of a harder alloy in the hot-finished condition than by specifying a harder temper of a softer alloy.

In thicknesses up to about ½ in., the tensile strength of hot-finished plates is approximately the same as that of the quarter hard temper. As the thickness increases, the strength of the plates approaches that of the soft temper.

Bars and rods in Type 1 alloys are commercially available hot finished or cold finished. As in the case of plates, there is an increasing amount of strain hardening of the metal as the size of the finished product decreases because of cooling during the rolling process. The hardening effect caused by the cold-finishing operations is also greater the smaller the size, since the actual reduction in area by cold work is a greater percentage reduction the smaller the size that comes to the finishing pass.

In the case of these products, the strength ranges from that of the soft temper for very large sections to that of the three-quarter hard temper for small sizes as shown in Table 2. However, the properties of any given size and type of product are very uniform from lot to lot. As in the case of plates, higher mechanical properties are obtained by the choice of a harder alloy, rather than by specifying a harder temper of a softer alloy.

Type 2 Alloys (Heat-Treated)—Type 2 alloys in the annealed temper have mechanical properties comparable with those of certain of the Type 1 alloys. By appropriate heat-treatment operations, the mechanical properties are greatly increased so that Type 2 alloys are suitable for structural applications where a high ratio of tensile and yield strengths to weight is required.

The yield strengths of Type 2 alloys may also be materially increased, with some sacrifice in their forming qualities, by subjecting them to small amounts of cold work after they have been heat-treated and aged.

The commercial useful tempers of the Type 2 wrought alloys comprise the annealed (O), the as-fabricated (F), and one or more of those which can be produced by combinations of thermal or thermal and mechanical treatments. In their simplest form, the temper designations for a heat-treated material consist of the letter T and an arabic number which indicates the general type of treatment used. The basic designations and their generic meanings are given in this General Information under the subhead Temper Designations. In some cases, two heat-treating

TABLE 2—*Approximate Tempers of the Various Sizes of Rod and Bar*

SHAPE	DIAMETER OR LEAST DISTANCE ACROSS FLATS	APPROXIMATE TEMPER[a]	
		Hot Finished	Cold Finished
Rounds, squares, and hexagons	Up to ¾ in., inclusive	—	H14 to H16 (½ to ¾H)
	Greater than ¾ and up to 1½ in.	—	H14 to H16 (½ to ¾H)
	Greater than 1½ and up to 8 in.	H12 (¼H)	—
Rectangles	Up to ⅛ in., inclusive	H12 to H14 (¼ to ½H)	H14 to H16 (½ to ¾H)
	Greater than ⅛ and up to ½ in.	H12 to H14 (¼ to ½H)	H14 (½H)
	Greater than ½ and up to 1½ in.	H12 (¼H)	H14 (½H)
	Greater than 1½ and up to 3 in.	H12 (¼H)	H14 (½H)

[a] Tempers shown are approximate. Minimum tensile strengths are not guaranteed, but experience indicates that the tempers shown may normally be expected. The smaller sizes tend to run harder than the large sizes since they finish colder from the rolls; also cold finishing introduces a greater percentage of reduction in cross-sectional area, hence more strain hardening.

practices generically the same but differing in details will result in different levels of properties. In cases like this, one or both of the resulting tempers may be designated by a symbol comprised of the letter T and two or more numbers. In general, however, the one developed first, or the one usually used, will carry the simple designation (such as T6) and the other will be designated by the more complex symbol (such as T61). The important things to remember are that a given symbol, regardless of alloy, always denotes the same type of treatment; and that, for a specific alloy, a given symbol always is associated with but one set of specification mechanical properties. In neither case does the symbol necessarily define the specific details of the treatment.

Aluminum Casting Alloys

SAE Standard

Report of Nonferrous Metals Division approved June 1911 and last revised by Nonferrous Metals Technical Committee January 1951.

TABLE 1—*Composition*[a] *of SAE Aluminum Casting Alloys*

SAE No.	ELEMENTS, %											
	Cu	Fe	Si	Mn	Mg	Zn	Ti	Ni	Cr	Sn	Other elements	
											Each	Total
300	5.5–7.5	1.5	5.0–6.0	0.8	0.2–0.6	0.8	0.2	—	—	—	—	0.8
304[b]	0.6	2.0	4.5–6.0	0.3	0.1	0.5	—	0.5	—	0.1	—	0.2
305[b]	0.6	2.0	11.0–13.0	0.3	0.1	0.5	—	0.5	—	0.1	—	0.2
306[b]	3.0–4.0	1.3	7.5–9.5	0.5	0.1	0.6	—	0.5	—	0.3	—	0.5
307[b]	3.0–4.5	2.0	4.5–5.5	0.5	0.1	1.0	—	0.5	—	0.3	—	0.5
308[b]	3.0–4.0	2.0	7.5–9.5	0.5	0.1	1.0	—	0.5	—	0.3	—	0.5
309[b]	0.6	2.0	9.0–10.0	0.3	0.4–0.6	0.5	—	0.5	—	0.1	—	0.2
310	0.3	1.0	0.25	0.3	0.5–0.65	5.2–6.0	0.1–0.25	—	0.4–0.6	—	0.05	0.15
320	0.1	0.5	0.3	0.3	3.5–4.5	0.1	0.2	—	—	—	0.05	0.15
321	0.5–1.5	1.3	11.0–13.0	0.1	0.7–1.3	0.1	0.2	2.0–3.0	—	—	0.05	—
322	1.0–1.5	0.8	4.5–5.5	0.5	0.4–0.6	0.3	0.2	—	0.2	—	0.05	0.15
323	0.2	0.6	6.5–7.5	0.3	0.2–0.4	0.3	0.2	—	—	—	0.05	0.15
324	0.2	0.3	0.2	0.1	9.5–10.6	0.1	0.2	—	—	—	0.05	0.15
326	3.3–4.3	1.0	5.5–7.0	0.5	0.1	1.0	0.2	0.3	—	—	—	0.5
327	1.0–2.0	1.0	7.0–8.6	0.2–0.6	0.2–0.6	1.0	0.3	0.2	0.3	—	—	0.5
328	1.0–2.0	0.9	11.0–13.0	0.5–0.9	0.4–1.0	0.4	0.2	0.05	—	—	—	0.5
329	3.0–4.5	1.2	5.5–7.0	0.8	0.5	1.0	0.2	0.5	—	—	—	0.5
33	6.0–8.0	1.4	1.0–4.0	0.5	0.07	2.5	0.2	0.3	—	—	—	0.5
330	4.0–5.0	1.0	5.0–6.0	0.5	0.1	1.0	0.2	—	—	—	—	0.5
331	3.0–4.5	1.2	8.0–10.0	0.8	0.6	1.0	0.2	0.5	—	—	—	0.5
332	2.0–4.0	1.2	8.5–10.5	0.5	0.5–1.5	0.5	0.2	0.5–1.5	—	—	—	0.5
34	9.2–10.8	1.5	2.0	0.5	0.15–0.35	0.5	0.2	0.3	—	—	—	0.3
35	0.6[c]	0.8	4.5–6.0	0.3	0.05	0.3	0.2	—	0.2	—	0.05	—
38	4.0–5.0	1.0	1.5	0.3	0.03	0.3	0.2	—	—	—	0.05	0.15
380	4.0–5.0	1.2	2.0–3.0	0.3	0.05	0.3	0.2	0.3	—	—	—	0.3
39	3.5–4.5	1.0	0.7	0.3	1.2–1.8	0.3	0.2	1.7–2.3	0.2	—	0.05	0.15

[a] Values are maximums except where indicated as a range. Aluminum is remainder.
[b] Die casting alloys.
[c] When so specified, Cu shall be 0.1% maximum.

SAE 300—Permanent-Mold Casting (Type 2 Alloy)

General Data—When the iron content approaches the maximum permitted, this alloy requires that special molding conditions be satisfied in order to secure sound castings. SAE 300 is being used extensively for gasoline engine pistons. An aging heat-treatment of 8 to 10 hr at 370 to 400 F (T5) is recommended in order to minimize changes in dimensions and mechanical properties as a result of service at elevated temperatures. The specific gravity of this alloy is approximately 2.89; its thermal conductivity is about 0.24 cgs units; it has a fair resistance to corrosion and good machinability.

Similar Specifications—SAE 300 is similar to ASTM B 108, Alloy CS66A.

Nominal Composition

Copper	6.5
Silicon	5.5
Magnesium	0.4

Physical Properties—Standard tension specimens separately cast in permanent metal molds, aged (T5) with the castings they represent and tested without machining shall have the following minimum properties:

Tensile strength, psi	32,000
Brinell hardness (500 kg, 10 mm)	95

SAE 304—Die Casting (Type 1 Alloy)

General Data—This alloy withstands salt-water corrosion very well and is, therefore, suitable for outboard-engine parts, marine fittings, or similar uses in corrosive locations. It casts well and can be used for complicated and rather thin-walled parts. The specific gravity of this alloy is approximately 2.69.

Similar Specifications—SAE 304 is similar to ASTM B 85 Alloy S4.

Nominal Composition

Silicon	5.0

Physical Properties—The typical properties of separately die

cast standard test specimens in the F (as-cast) temper should be approximately as follows:

Tensile strength, psi	30,000
Elongation in 2 in., %	5.0
Charpy (40 mm span), ft-lb	4.5

SAE 305—Die Casting (Type 1 Alloy)

General Data—This alloy is especially resistant to salt-water corrosion. Because of its fluidity and freedom from hot shortness, it can be used for thin-walled castings or for complicated castings consisting of both thin and heavy sections. The specific gravity of this alloy is approximately 2.66.

Similar Specifications—SAE 305 is similar to ASTM B 85, Alloy S5, and to AMS 4290.

Nominal Composition

Silicon	12.0

Physical Properties—The typical properties of separately die-cast standard test specimens in the F (as-cast) temper should be approximately as follows:

Tensile strength, psi	37,000
Elongation in 2 in., %	1.8
Charpy (40 mm span), ft-lb	2.0

SAE 306 and 308—Die Casting (Type 1 Alloy)

General Data—These alloys have good foundry characteristics, good physical properties, and a reasonably satisfactory resistance to corrosion. They are, basically, a modification of SAE 307, but have better foundry characteristics, and are being used to a considerable extent for general casting purposes. SAE 306 is intended for cold-chamber casting machines; but SAE 308, because of its higher limits for iron and zinc, can be used for castings made in gooseneck-type casting machines as well as in cold-chamber machines. Both compositions have a specific gravity of approximately 2.76.

Similar Specifications—SAE 306 is similar to ASTM B 85, Alloy SC6, and to AMS 4291. SAE 308 is similar to ASTM B 85, Alloy SC7.

Nominal Composition

Silicon	8.5
Copper	3.5

Physical Properties—The typical properties of separately die-cast test specimens in the F (as-cast) temper should be approximately as follows:

	SAE 306	SAE 308
Tensile strength, psi	41,000	43,000
Elongation in 2 in., %	3.0	2.0
Charpy (40 mm span), ft-lb	3.5	3.2

SAE 307—Die Casting (Type 1 Alloy)

General Data—This is a relatively inexpensive general-purpose alloy used extensively for simple castings which do not have very thin walls and do not require the maximum in resistance to corrosion. The specific gravity of this alloy is approximately 2.78.

Similar Specifications—SAE 307 is similar to ASTM B 85, Alloy SC2.

Nominal Composition

Silicon	5.0
Copper	4.0

Physical Properties—The typical properties of separately die-cast standard test specimens in the F (as-cast) temper should be approximately as follows:

Tensile strength, psi	38,000
Elongation in 2 in., %	2.5
Charpy (40 mm span), ft-lb	2.5

SAE 309—Die Casting (Type 1 Alloy)

General Data—This alloy has excellent casting characteristics and a high resistance to corrosion. It is particularly well suited for use in thin-walled or intricate castings produced in cold-chamber casting machines. It is the alloy normally substituted for SAE 305 in those instances where the method of casting is changed from the gooseneck to the cold-chamber process. The specific gravity of the alloy is about 2.64.

Similar Specifications—SAE 309 is similar to ASTM B 85, Alloy SG3, and to AMS 4290.

Nominal Composition

Silicon	9.5
Magnesium	0.5

Physical Properties—The typical properties of separately die-cast standard test specimens in the F (as-cast) temper should be approximately as follows:

Tensile strength, psi	43,000
Elongation in 2 in., %	3.0
Charpy (40 mm span), ft-lb	2.7

SAE 310—Sand Casting (Type 1 Alloy)

General Data—This is a general-purpose alloy which develops high mechanical properties and a good ductility when aged for four weeks at room temperature (T5) or for 9 to 11 hr at 340 to 360 F (T51). Within the first two weeks after casting, or before artificial aging, the alloy has a high ductility, permitting severe cold deformation. Since the alloy does not require a high-temperature solution heat-treatment, it can be used as an alternate for SAE 38 alloy if heat-treating facilities are not available. The alloy has good casting properties and can be machined easily. The typical yield strength is 25,000 psi. Its specific gravity is approximately 2.80.

Similar Specifications—SAE 310 is similar to ASTM B 26, Alloy ZG61A.

Nominal Composition

Zinc	5.6
Magnesium	0.6
Chromium	0.5
Titanium	0.2

Physical Properties—Standard tension-test specimens sepa-

rately cast in sand molds and aged (T5 or T51) shall have the following minimum properties:

Tensile strength, psi	30,000
Elongation in 2 in., %	3

SAE 320—Sand Casting (Type 1 Alloy)

General Data—This alloy has the highest resistance to severely corrosive conditions of the aluminum alloys used for general casting purposes. It has good physical properties and is readily machinable. It is used for carburetor cases, cast pipe fittings, and other castings for which high resistance to corrosion is required. The specific gravity of the alloy is approximately 2.64.

Similar Specifications—SAE 320 is similar to ASTM B 26, Alloy G4A.

Nominal Composition

Magnesium	4.0

Physical Properties—Standard tension-test specimens separately cast in sand and tested without machining shall have the following minimum properties in the F (as-cast) temper:

Tensile strength, psi	22,000
Elongation in 2 in., %	6

SAE 321—Permanent-Mold Casting (Type 2 Alloy)

General Data—This alloy usually is used in the production of pistons for automobile engines because of its low coefficient of thermal expansion as compared with other aluminum alloys, its hardness and resistance to wear, and its good physical properties at elevated temperatures. The alloy can be used in the production of sand castings. The T551 temper is an aging treatment of about 14 to 18 hr at 330 to 350 F applied to as-cast material to stabilize the properties and dimensions against change at elevated temperatures. The specific gravity of this alloy is approximately 2.70, and its thermal conductivity is approximately 0.28 cgs units.

Similar Specifications—SAE 321 is similar to ASTM B 108, Alloy SN122A.

Nominal Composition

Silicon	12.0
Nickel	2.5
Copper	1.0
Magnesium	1.0

Physical Properties—Standard tension-test specimens separately cast in permanent metal molds shall have the following minimum properties:

Temper	T551
Tensile strength, psi	31,000

SAE 322—Sand and Permanent-Mold Casting (Type 2 Alloy)

General Data—This alloy has excellent foundry characteristics and resistance to corrosion, and it retains its strength well at elevated temperatures. It is used in the production of water-cooled cylinder heads for automotive or aircraft engines and for similar applications where the production of sound, leak-proof castings of intricate design is of importance. The T6 temper combines a solution treatment of 8 to 12 hr at about 980 F with an aging treatment at 300 to 320 F for 3 to 5 hr. The T51 temper is an aging treatment for 7 to 9 hr at 430 to 450 F. The T71 temper combines the solution treatment with stabilizing for 4 to 6 hr at 465 to 485 F in order to attain a high strength with stability. The specific gravity of the alloy is approximately 2.67.

Similar Specifications—SAE 322 is similar to ASTM B 26, and ASTM B 108, Alloy SC51A. SAE 322 sand casting T6 temper is similar to AMS 4212; T51 temper is similar to AMS 4210; and T71 temper is similar to AMS 4214. SAE 322 permanent mold casting T6 temper is similar to AMS 4281, and T71 temper is similar to AMS 4280.

Nominal Composition

Silicon	5.0
Copper	1.2
Magnesium	0.5

Physical Properties—Standard tension-test specimens separately cast in sand or in permanent metal molds and heat-treated with the castings they represent shall have the following minimum properties:

	SAND			PERMANENT MOLD		
Temper	T6	T51	T71	T6	T51	T71
Tensile strength, psi	32,000	25,000	30,000	37,000	26,000	34,000
Elongation in 2 in., %	2	—	—	1.5	—	—

SAE 323—Sand and Permanent-Mold Casting (Type 2 Alloy)

General Data—Like other aluminum alloys in which silicon is the principal alloying element, this alloy has excellent foundry characteristics and resistance to corrosion. Its physical properties are somewhat lower than those of the alloy covered by SAE 38, but it is commonly used for the production of high-strength castings which are too intricate to produce in that alloy without excessive losses in the foundry. It is also preferred where high strength castings are required for use under severely corrosive conditions. The T6 temper combines a solution treatment of 8 to 12 hr at about 1000 F with an aging treatment of 2 to 3 hr at 300 to 320 F to secure high strength. The T51 temper is an aging treatment of 7 to 9 hr at 430 to 450 F applied to intricate castings which cannot safely be given a solution treatment. The specific gravity of the alloy is approximately 2.65.

Similar Specifications—SAE 323 is similar to ASTM B 26, and ASTM B 108, Alloy SG70A; and to AMS 4217 and AMS 4284.

Nominal Composition

Silicon	7.0
Magnesium	0.3

Physical Properties—Standard tension-test specimens separately cast in sand or in permanent metal molds, heat-treated with the castings they represent, and tested without machining shall have the following minimum properties:

(*Continued on next page.*)

	SAND		PERMANENT MOLD
Temper	T6	T51	T6
Tensile strength, psi	30,000	23,000	33,000
Elongation in 2 in., %	3	—	3

SAE 324—Sand Casting (Type 2 Alloy)

General Data—This alloy, because of its high physical properties, is used in the production of castings that require the maximum ratio of strength to weight and ruggedness under severe abuse. As an example of its serviceability, its use for trucks, end sills, and other parts of railway cars is cited. It is used in aircraft fittings and other castings that require maximum strength and ruggedness. The alloy requires special foundry practices, however, and it is not well suited for complicated or thin-section castings. The castings normally are supplied in the solution heat-treated (T4) condition. The usual T4 treatment is about 16 hr at 810 F followed by a quench in 300 F oil. The specific gravity of the alloy is approximately 2.55.

Similar Specifications—SAE 324 is similar to ASTM B 26, Type G10A; and to AMS 4240.

Nominal Composition

Magnesium	10.0

Physical Properties—Standard tension-test specimens separately cast in sand, heat-treated with the castings they represent (T4 temper), and tested without machining shall have the following minimum properties:

Tensile strength, psi	42,000
Elongation in 2 in., %	12

SAE 326—Sand and Permanent-Mold Casting (Type 2 Alloy)

General Data—This alloy is a low-cost, general-purpose alloy used in those applications where its properties will meet the requirements. Although the alloy is heat-treatable, it is used to a considerable extent in the as-cast condition. It has good machinability and casting characteristics and a fair resistance to corrosion. Its specific gravity is about 2.77. The T6 temper is a solution treatment of 6 to 12 hr at 930 to 950 F followed by an aging treatment of 3 to 5 hr at 300 to 320 F.

Similar Specifications—SAE 326 is similar to ASTM B 26, and ASTM B 108, Alloy SC64B.

Nominal Composition

Silicon	6.3
Copper	3.8

Physical Properties—Standard tension-test specimens separately cast in sand or permanent metal molds, heat-treated with the castings they represent, and tested without machining, shall have the following minimum properties:

	SAND		PERMANENT MOLD	
Temper	F (as-cast)	T6	F (as-cast)	T6
Tensile strength, psi	24,000	30,000	26,000	33,000
Elongation in 2 in., %	2.0	2.5	2.0	4.0

SAE 327—Sand Casting (Type 2 Alloy)

General Data—This alloy is used as an alternate for SAE 322 and 323, has rather similar characteristics, and is normally less expensive. It has good casting characteristics and resistance to corrosion, and it retains its strength fairly well at moderately elevated temperatures.

The T6 temper is a solution treatment of 8 to 12 hr at 930 to 950 F followed by an aging treatment for 3 to 5 hr at 300 to 320 F. Its specific gravity is approximately 2.68.

Similar Specifications—SAE 327 is similar to ASTM B 26, Alloy SC82A.

Nominal Composition

Silicon	7.8
Copper	1.5
Manganese	0.4
Magnesium	0.4

Physical Properties—Standard tension-test specimens separately cast in sand, heat-treated and aged (T6) with the castings they represent, and tested without machining shall have the following minimum properties:

Temper	F (as-cast)	T6
Tensile strength, psi	25,000	34,000
Elongation in 2 in., %	1	1

SAE 328—Permanent-Mold Casting (Type 2 Alloy)

General Data—This alloy is very similar to SAE 321 and under normal conditions should be slightly less expensive. It is used for little else but pistons for internal-combustion engines. The T5 temper is an aging treatment of 8 to 12 hr at 365 to 385 F applied to as-cast material. Its specific gravity is approximately 2.68.

Similar Specifications—SAE 328 is similar to ASTM B 108, Alloy SC122A.

Nominal Composition

Silicon	12.0
Copper	1.5
Manganese	0.7
Magnesium	0.7

Physical Properties—Standard tension-test specimens separately cast in permanent metal molds, heat-treated (T5) with the castings they represent, and tested without machining shall have the following minimum properties:

Tensile strength, psi	32,000

SAE 329—Sand Casting (Type 2 Alloy)

General Data—This alloy is a low-cost, general-purpose, sand-casting alloy similar to SAE 326 but with a slightly lower elongation. It combines good foundry characteristics with good machinability and a fair resistance to corrosion, but it is not generally recommended where shock-type loads are to be expected. It is rather commonly used in the as-cast F temper, but a number of tempers resulting from various heat-treatments are possible. The T6 temper is a solution treatment of about 12 hr at 930 to 950 F

followed by aging for about 2 to 5 hr at 300 to 320 F. The specific gravity of the alloy is about 2.74.

Similar Specifications—SAE 329 is similar to ASTM B 26, and ASTM B 108, Alloy SC64C.

Nominal Composition

Silicon	6.3
Copper	3.5

Physical Properties—Standard tension-test specimens separately cast in sand, heat-treated with the castings they represent, and tested without machining shall have the following minimum properties:

Temper	F (as-cast)	T6
Tensile strength, psi	23,000	31,000
Elongation in 2 in., %	—	1.5

SAE 33—Sand and Permanent-Mold Casting (Type 1 Alloy)

General Data—This alloy is widely used as a general casting alloy. It is normally used in the as-cast condition, although annealing treatments will somewhat improve its elongation. Its resistance to corrosion is only fair, but it can be machined rather easily. It is used for crankcases, oil pans, differential carriers, transmission cases, camshaft housings, cylinder heads for water-cooled automobile engines, and similar parts. The specific gravity of the alloy is approximately 2.84.

Similar Specifications—SAE 33 is similar to ASTM B 26, and ASTM B 108, Alloy CS72A.

Nominal Composition

Copper	7.0
Silicon	2.5

Physical Properties—Standard tension-test specimens separately cast in sand or in permanent metal molds and tested without machining shall have the following minimum properties in the F (as-cast) temper:

	SAND	PERMANENT MOLD
Tensile strength, psi	19,000	23,000

SAE 330—Permanent-Mold Casting (Type 1 Alloy)

General Data—This alloy is a good, general-purpose alloy with excellent foundry characteristics, a fair resistance to corrosion, moderate strength, and good machinability. Its specific gravity is about 2.77.

Similar Specifications—SAE 330 is similar to ASTM B 108, Alloy SC64A.

Nominal Composition

Silicon	5.5
Copper	4.5

Physical Properties—Standard tension-test specimens separately cast in a permanent metal mold and tested, in the F (as-cast) temper, without machining shall have the following minimum properties:

Tensile strength, psi	23,000

SAE 331—Permanent-Mold Casting (Type 2 Alloy)

General Data—This is a low-cost alloy rather similar to SAE 326, 329, and 330 but somewhat superior to them for the production of permanent-mold castings. The alloy has very good foundry characteristics, a fair resistance to corrosion, and good machinability. It has been used for clutch housings, carburetor parts, and hydraulic-brake parts. The T5 temper is produced by aging the as-cast material for about 8 hr at 390 to 410 F. The T6 temper combines a solution heat-treatment of about 9 hr at 930 to 950 F with an aging treatment of 2 to 5 hr at 300 to 320 F, while the T7 temper combines this same solution heat-treatment with an aging treatment of 4 to 6 hr at 490 to 510 F. Its specific gravity is approximately 2.76.

Nominal Composition

Silicon	9.0
Copper	3.8

Physical Properties—Standard tension-test specimens separately cast in permanent metal molds, heat-treated with the castings they represent, and tested without machining, shall have the following minimum tensile strength:

Temper	F (as-cast)	T5	T6	T7
Tensile strength, psi	28,000	30,000	35,000	31,000

SAE 332—Permanent-Mold Casting (Type 2 Alloy)

General Data—This alloy is primarily intended for use in automotive-engine pistons and has to a very considerable extent superseded SAE 321 and 34 for that use The alloy has a specific gravity of about 2.74, a thermal conductivity (T5 temper) of about 0.26 cgs units, and a coefficient of thermal expansion (68–572 F) of about 12.4×10^{-6} in. per in. It is usually used in the T5 temper, which is produced by aging the casting for about 8 hr at 390 to 410 F.

Nominal Composition

Silicon	9.5
Copper	3.0
Magnesium	0.8
Nickel	0.8

Physical Properties—Standard tension specimens separately cast in permanent metal molds, heat-treated with the castings they represent, and tested without machining shall have the following minimum tensile strength:

Temper	T5
Tensile strength, psi	31,000

SAE 34—Sand and Permanent-Mold Casting (Type 2 Alloy)

General Data—This alloy has been used for many years for automobile-engine pistons, and, in the form of sand castings, for aircooled-engine cylinder heads but has largely been superseded by SAE 300, 321, 328, or 39. The use of this alloy in new designs is not recommended.

The T2 temper results from an annealing treatment of 2 to 4 hr at 590 to 610 F, while the T551 temper is an aging treatment of 18 to 22 hr at 330 to 350 F selected to minimize dimensional changes at elevated temperatures. The T61 temper is a solution

treatment of 8 to 12 hr at 940 to 960 F followed by an aging treatment of 10 to 12 hr at 300 to 320 F. The solution treatment for T65 is the same as for T61; however, the aging treatment is 7 to 9 hr at 330 to 350 F. The specific gravity of this alloy is approximately 2.95.

Similar Specifications—SAE 34 is similar to ASTM B 26, and ASTM B 108, Alloy CG100A.

Nominal Composition

Copper	10.0
Magnesium	0.25

Physical Properties—Standard tension-test specimens separately cast in sand or permanent metal molds, heat-treated with the castings they represent, and tested without machining shall have the following minimum tensile properties:

	SAND		PERMANENT MOLD	
Temper	T2	T61	T551	T65
Tensile strength, psi	23,000	30,000	30,000	40,000

SAE 35—Sand and Permanent-Mold Casting (Type 1 Alloy)

General Data—This alloy has excellent foundry and casting characteristics and good resistance to corrosion. Where severe corrosive conditions prevail, a maximum copper content of 0.1% is preferred. SAE 35 is used for general casting purposes, particularly for large and intricate castings having both thin and heavy sections. It is also used for castings that must be leak proof under pressure. It is cast both in sand and in permanent metal molds. It is used for automobile-body parts, manifolds, instruments, and a variety of parts in which the higher mechanical properties of the Type 2 alloys are not required. Its specific gravity is approximately 2.66.

Similar Specifications—SAE 35 is similar to ASTM B 26, and ASTM B 108, Alloy S5B.

Nominal Composition

Silicon	5.0

Physical Properties—Standard tension-test specimens separately cast in sand or in permanent metal molds and tested without machining shall have the following minimum properties in the F (as-cast) temper:

	SAND	PERMANENT MOLD
Tensile strength, psi	17,000	21,000
Elongation in 2 in., %	3.0	2.5

SAE 38—Sand Casting (Type 2 Alloy)

General Data—This alloy was the first of the high-strength, heat-treated alloys of aluminum to be put in commercial production. It is still one of the most widely used of this type of alloys. It has good resistance to corrosion and is used extensively in the manufacture of outboard motors and for castings for use on shipboard. Because of its superior physical properties, it has found application in windshield frames; fire-engine, motorcoach, and aircraft-engine crankcases; and in a variety of parts in both motor-vehicle and aircraft assemblies where a high-strength, light-weight casting is desired. The T4 temper is a solution treatment of about 12 hr at 950 to 970 F which produces moderately high strength in combination with high elongation and shock resistance. The T6 and T62 tempers combine the solution treatment with aging treatment of 3 to 5 hr (T6) or 12 to 16 hr (T62) at 300 to 320 F to secure greater strength at a sacrifice in ductility. The T7 treatment combines the solution treatment with a stabilizing treatment of 4 to 6 hr at 490 to 510 F and is particularly useful for castings exposed to elevated temperatures. The properties of castings given the T4 treatment will approach those quoted for the T6 temper after a few months aging at room temperature. The specific gravity of the alloy is approximately 2.77.

Similar Specifications—SAE 38 is similar to ASTM B 26, Alloy C4A. The T4 temper is similar to AMS 4230, and the T6 temper is similar to AMS 4231.

Nominal Composition

Copper	4.5
Silicon	0.8

Physical Properties—Standard tension-test specimens separately cast in sand and heat-treated with the castings they represent shall have the following minimum properties:

Temper	T4	T6	T62	T7
Tensile strength, psi	29,000	32,000	36,000	29,000
Elongation in 2 in., %	6.0	3.0	—	3.0

SAE 380—Permanent-Mold Casting (Type 2 Alloy)

General Data—This alloy is a modification of SAE 38 in which the silicon content is increased to permit casting in permanent molds. It is used for much the same purposes as SAE 38. The T4 temper is a solution treatment of about 8 hr at 940 to 960 F. The T6 temper combines the solution treatment and an aging treatment of 5 to 7 hr at 300 to 320 F, and the T7 temper combines the solution treatment with a stabilizing treatment of 4 to 6 hr at 490 to 510 F. The specific gravity of this alloy is approximately 2.78.

Similar Specifications—SAE 380 is similar to ASTM B 108, Alloy CS42A. The T4 temper is similar to AMS 4283; and the T6 temper is similar to AMS 4282.

Nominal Composition

Copper	4.5
Silicon	2.5

Physical Properties—Standard tension-test specimens separately cast in permanent metal molds and heat-treated with the castings they represent shall have the following minimum properties:

Temper	T4	T6	T7
Tensile strength, psi	33,000	35,000	33,000
Elongation in 2 in., %	4.5	2.0	3.0

(*Continued on next page.*)

SAE 39—Sand and Permanent-Mold Casting (Type 2 Alloy)

General Data—This alloy, like SAE 34, 321, and 322, retains its strength at elevated temperatures better than most of the alloys that are used for general casting purposes. It is used for pistons and cylinder heads of aircraft engines and for other castings that operate at elevated temperatures. The T21 temper is an annealing treatment of 2 to 4 hr at 640 to 660 F to relieve casting strain while the T571 temper is an aging treatment of 40 to 48 hr at 330 to 350 F applied to as-cast material to minimize changes in properties or dimensions during service at elevated temperatures. The T61 temper in both cases combines a solution treatment of about 6 hr at 950 to 970 F (quench in air blast) with an aging treatment of 1 to 3 hr at 440 to 460 F for sand castings, or 3 to 5 hr at 390 to 410 F for permanent-mold castings. The specific gravity of the alloy is approximately 2.75.

Similar Specifications—SAE 39 is similar to ASTM B 26, and ASTM B 108, Alloy CN42A; and to AMS 4220 and 4222.

Nominal Composition

Copper	4.0
Nickel	2.0
Magnesium	1.5

Physical Properties—Standard tension-test specimens separately cast in sand or permanent metal molds and heat-treated with the castings they represent shall have the following minimum properties:

	SAND		PERMANENT MOLD	
Temper	T21	T61	T571	T61
Tensile strength, psi	23,000	32,000	34,000	40,000

Wrought Aluminum Alloys

SAE Standard

Report of Nonferrous Metals Division approved June 1911 and last revised by Nonferrous Metals Technical Committee January 1950.

TABLE 1—*Compositions*[a] *of SAE Wrought Aluminum Alloys*

SAE No.	ELEMENTS, %									Other elements	
	Cu	Fe	Si	Mn	Mg	Zn	Cr	Ti	Ni	Each	Total
20	0.20	0.7	0.3	1.0–1.5	0.8–1.3	0.10	—	—	—	0.05	0.15
201	0.10	Fe + Si = 0.45 max.		0.10	2.2–2.8	0.20	0.15–0.35	—	—	0.05	0.15
24	3.8–4.9	0.5	0.5	0.3–0.9	1.2–1.8	0.10	0.10	—	—	0.05	0.15
240, Core	3.8–4.9	0.5	0.5	0.3–0.9	1.2–1.8	0.10	0.10	—	—	0.05	0.15
240, Coating	0.1	Fe + Si = 0.7 max.		0.05	—	0.10	—	—	—	[b]	[b]
25	0.2	Fe + Si = 1.0 max.		0.10	—	0.10	—	—	—	0.05	0.15
26	3.5–4.7	1.0	0.8	0.4–1.0	0.2–0.8	0.25	0.10	0.15	—	0.05	0.15
260	3.9–5.0	1.0	0.5–1.2	0.4–1.2	0.2–0.8	0.25	0.10	0.15	—	0.05	0.15
270	3.5–4.5	1.0	0.9	0.2	0.45–0.9	0.25	0.10	0.15	1.7–2.3	0.05	0.15
280	0.35	1.0	0.6–1.2	0.2	0.45–0.8	0.25	0.15–0.35	0.15	—	0.05	0.15
281	0.15–0.4	0.7	0.4–0.8	0.15	0.8–1.2	0.20	0.15–0.35	0.15	—	0.05	0.15
282	0.10	0.35	[c]	0.10	1.1–1.4	0.10	0.15–0.35	0.15	—	0.05	0.15
29	0.2	0.7	0.6	1.0–1.5	—	0.10	—	—	—	0.05	0.15
290	0.5–1.3	1.0	11.5–13.5	0.2	0.8–1.3	0.25	0.10	0.15	0.5–1.3	0.05	0.15

[a] Percentages are maximum except where indicated as a range. Aluminum is remainder.
[b] Aluminum is 99.3% minimum by difference.
[c] Silicon is 45 to 65% of magnesium content.

SAE 20—(Type 1 Alloy)

General Data—This alloy has strengths significantly higher than those of SAE 25 and 29 and only slightly lower than those of SAE 201. Its workability is a little better than that of SAE 201 but is not as good as that of SAE 25 and 29. It has a high resistance to corrosion. It is commercially available in the form of sheet, plate, and tubing and is used for body panels and fluid lines.

Similar Specifications—SAE 20 is similar to ASTM B 209. Alloy MG11A.

Nominal Composition

Manganese	1.2
Magnesium	1.0

Physical Properties—The properties of the material in the form of sheet are shown in Table 1. The strengths of tubing are approximately the same as those for sheet. Typical yield

strengths, shearing strengths, and endurance limits are given in Table 2.

TABLE 1—*Minimum Properties for SAE 20 Sheet*

TEMPER	TENSILE STRENGTH, PSI	PER CENT ELONGATION[a] IN 2 IN. FOR VARIOUS THICKNESSES				
		0.249 to 0.114 in.	0.113 to 0.051 in.	0.050 to 0.032 in.	0.031 to 0.020 in.	0.019 to 0.013 in.
O	29,000[b]	18	18	16	14	10
H32	28,000	6	5	4	3	1
H34	32,000	5	4	3	3	1
H36	35,000	4[c]	3	3	2	1
H38	38,000	4[d]	4	3	2	1

[a] Test specimens from sheet in the H32 and H34 tempers are taken parallel to the direction of rolling.
[b] Maximum. So specified to insure complete annealing.
[c] Maximum commercial thickness is 0.162 in.
[d] Maximum commercial thickness is 0.128 in.

TABLE 2—*Typical Yield Strength, Shearing Strength, and Endurance Limit of SAE 20*

TEMPER	YIELD STRENGTH,[a] PSI	SHEARING STRENGTH, PSI	ENDURANCE LIMIT,[b] PSI
O	10,000	16,000	14,000
H32	22,000	17,000	14,500
H34	27,000	18,000	15,000
H36	31,000	20,000	15,500
H38	34,000	21,000	16,000

[a] Yield strength is defined as the stress which produces a permanent set of 0.2% of the initial gage length.
[b] R. R. Moore type specimen; 500,000,000 cycles.

SAE 201—(Type 1 Alloy)

General Data—This alloy is manufactured in the form of sheets, plates, bars, rods, wire, and tubing. In the form of sheet, it is used for aircraft gasoline tanks, engine cowling, and other moderately stressed parts; and for panels, roof sheets, and similar applications in truck and bus construction. In tubing it is used for fuel and instrument lines. The alloy is the strongest of the Type I alloys, has a very high resistance to corrosion, and retains its strength well after fusion welding. It is not, however, as easily formed as SAE 25 and 29.

Similar Specifications—SAE 201 is similar to ASTM B 209, B 210, and B 211, Alloy GR20A; and to AMS 4015, 4016, 4017, 4070, and 4071. The commercial designation of SAE 201 is 52S.

Nominal Composition

Magnesium	2.5
Chromium	0.25

Physical Properties—The minimum properties of this alloy in the form of sheet are shown in Table 1. The properties of tubing are similar, but not identical to those of the sheet. Rods and bars are supplied in the hot-finished and cold-finished conditions, for which the approximate tempers are shown in the table in the SAE General Information on Aluminum Alloys in the section on wrought alloys. The properties of sheet in the corresponding tempers may be used, with the usual factors of safety, for purposes of design.

The yield strength in the soft temper is about 12,000 psi; in the harder tempers it is about 80 to 90% of the tensile strength. Although plate is normally purchased in the hot-finished condition, it can be secured if needed, in the annealed condition in thicknesses up to 3 in.; in the H32(¼H) condition in thicknesses up to 2 in.; and in the H34(½H) condition up to 1 in. Typical values of shearing strength and endurance limit are given in Table 2.

TABLE 1—*Minimum Properties of SAE 201 Sheet*

TEMPER	TENSILE STRENGTH, PSI	PER CENT ELONGATION[a] IN 2 IN., FOR VARIOUS THICKNESSES						
		0.249 to 0.162 in.	0.161 to 0.114 in.	0.113 to 0.051 in.	0.050 to 0.032 in.	0.031 to 0.020 in.	0.019 to 0.013 in.	0.012 to 0.008 in.
O (soft)	31,000[b]	20	20	20	20	18	15	15
H32 (¼ hard)	31,000	9	9	7	5	5	4	—
H34 (½ hard)	34,000	7	7	6	4	4	3	3
H36 (¾ hard)	37,000	—	4	4	4	3	3	3
H38 (hard)	39,000	—	4	4	4	3	3	3

[a] Test specimens taken parallel to direction of rolling from flat and coiled sheet in H32(¼H) and H34(½H) tempers.
[b] Maximum. So specified to insure complete annealing.

TABLE 2—*Typical Values of Shearing Strength and Endurance Limit of SAE 201*

TEMPER	APPROXIMATE SHEARING STRENGTH, PSI	APPROXIMATE ENDURANCE LIMIT, PSI
O (soft)	18,000	17,000
H32 (¼ hard)	20,000	17,500
H34 (½ hard)	21,000	18,000
H36 (¾ hard)	23,000	18,500
H38 (hard)	24,000	19,000

SAE 24—(Type 2 Alloy)

General Data—This alloy is available in most commercial forms (except rolled structural shapes and forgings) and is the alloy currently used for structural applications where high strength is required. It has a good resistance to corrosion in most environments, but protective coatings are recommended if the corrosive conditions are severe. Improper heat-treating practices also may reduce the resistance to corrosion without affecting the strength. While a liberal bend radius is required for heat-treated material, the formability immediately after quenching is very good. This improved formability can be retained for a considerable period of time by storing the material at about 0 F immediately after quenching, and forming soon after removal from the cold storage. Difficult forming can be accomplished with annealed material, but the formed parts should be heat-treated before entering the final assembly. Plates are commercially available in thicknesses up to 3 in., tubing up to about 9 in. outside diameter, bars and rods in sizes up to 24 sq in. in cross-sectional area, and extrusions in sizes up to 32 sq in. in cross-sectional area.

Similar Specifications—SAE 24 is similar to ASTM B 209, B 210, B 211, B 221, and B 235, Alloy CG42A; and to AMS

4035, 4037, 4086, 4087, 4088, 4120, and 4152. The commercial designation for SAE 24 is 24S.

Nominal Composition

Copper	4.5
Magnesium	1.5
Manganese	0.6

Physical Properties—In the form of sheet, the alloy has the properties shown in Table 1. Other products have comparable, although not identical, properties.

TABLE 1—*Properties of SAE 24*

TEMPER	MINIMUM TENSILE STRENGTH, PSI	MINIMUM YIELD STRENGTH, PSI	MINIMUM ELONGATION IN 2 IN., %	APPROXIMATE SHEARING STRENGTH, PSI	APPROXIMATE ENDURANCE LIMIT, PSI
O (soft)	32,000[a]	14,000[a]	12	18,000	13,000
T4 (heat-treated)	62,000[b]	40,000[b]	12	41,000	18,000
T36 (rolled after heat-treatment)	69,000	52,000	10	42,000	18,000

[a] Maximum.
[b] These strengths are for coiled sheet and plate up to 1 in. thick and for flat sheet heat-treated by the user. Flat sheet as supplied by the manufacturer has strengths at least 2000 psi higher and is identified by the temper symbol T3.

SAE 240—(Type 2 Alloy)

General Data—This product is available only in the form of sheet and plate and is a composite material consisting of a core of SAE 24 coated on both sides with aluminum of relatively high purity. Its general characteristics are similar to those of SAE 24 except that it has an extremely high resistance to corrosion, and it is somewhat less susceptible to damage by improper heat-treatment. It can, therefore, often be used without protection in environments where painting of SAE 24 would be necessary. In addition to the properties listed below, several other combinations of properties can be obtained by working and aging the material after the solution heat-treatment. The thickness of the coating is less on sheet more than 0.063-in. thick than on lighter gage material; hence, the strengths of sheet more than 0.063-in. thick are greater than those of thinner material.

Similar Specifications—SAE 240 is similar to ASTM B 209, Alloy Clad CG42A; and to AMS 4040, 4041, and 4042. The commercial designation for SAE 240 is Clad 24S.

TABLE 1—*Properties of SAE 240 Sheet*

TEMPER	TENSILE STRENGTH, PSI		YIELD STRENGTH, PSI		MINIMUM ELONGATION IN 2 IN., %
	Less than 0.064 in. thick	0.064 in. thick or over	Less than 0.064 in. thick	0.064 in. thick or over	
O (soft)	30,000[a]	32,000[a]	14,000[a]	14,000[a]	8
T4 (heat-treated)	58,000[b]	61,000[b]	37,000[b]	38,000[b]	12
T36 (rolled after heat-treatment)	62,000[c]	66,000[c]	48,000[c]	50,000[c]	8

[a] Maximum. Specified in order to insure complete annealing.
[b] These strengths are minimum for coiled sheet and sheet heat treated by the user. Flat sheet as supplied by the manufacturer has minimum strengths about 2000 psi higher and is identified by the temper symbol T3.
[c] Minimum.

Nominal Composition

(Core)	Copper	4.5
	Magnesium	1.5
	Manganese	0.6
(Coating)	Aluminum	99.3 minimum (by difference)

Physical Properties—The physical properties of this materia in sheet form are shown in Table 1.

SAE 25—(Type 1 Alloy)

General Data—This specification covers aluminum of com mercial purity, a material which is available in most of the form into which metals are fabricated. The material has excellen forming qualities and can be spun, stamped, or drawn into al most any desired shape, depending somewhat on the temper o the material selected for the operation. Its resistance to corro sion is excellent, but its physical properties are not especiall high. It is used for such purposes as gasoline and oil tanks an lines, truck tanks for milk or gasoline, body panels, instrumen dials, and miscellaneous low-stressed parts.

Similar Specifications—SAE 25 is similar to ASTM B 209 B 210, and B 211, Alloy 990A; and to AMS 4001, 4003, an 4062. The commercial designation for SAE 25 is 2S.

Nominal Composition

Aluminum	99.0 minimum (by difference)

Physical Properties—The properties of the material in th form of sheet are shown in Table 1. Other products have com

TABLE 1—*Minimum Properties of SAE 25 Sheet*

GRADE AND TEMPER	TENSILE STRENGTH, PSI	PER CENT ELONGATION[a] IN 2 IN., FOR VARIOUS THICKNESSES						
		0.250 to 0.162 in.	0.161 to 0.114 in.	0.113 to 0.051 in.	0.050 to 0.032 in.	0.031 to 0.020 in.	0.019 to 0.013 in.	0.012 to 0.008 in.
O (soft)	15,500[b]	30	30	30	25	20	15	15
H12 (¼ hard)	14,000	9	9	8	6	4	3	—
H14 (½ hard)	16,000	6	6	5	4	3	2	1
H16 (¾ hard)	19,000	—	4	4	3	2	1	1
H18 (hard)[c]	22,000	—	4[c]	4	3	2	1	1

[a] In the H12(¼H) and H14(½H) tempers, test specimens are taken parallel to th direction of rolling.
[b] Maximum. So specified to insure complete annealing.
[c] The maximum thickness commercially available in the hard temper is 0.128 in.

TABLE 2—*Typical Values of Shearing Strength and Endurance Limit of SAE 25*

TEMPER	APPROXIMATE SHEARING STRENGTH, PSI	APPROXIMATE ENDURANCE LIMIT, PSI
O (soft)	9,500	5,000
H12 (¼ hard)	10,000	6,000
H14 (½ hard)	11,000	7,000
H16 (¾ hard)	12,000	8,500
H18 (hard)	13,000	8,500

parable, although not identical, properties. Rods and bars are produced only in the hot-finished and cold-finished conditions, for which the approximate tempers are shown in the table in the SAE General Information on Aluminum Alloys. The properties of the corresponding tempers of sheet can be used, with the usual factors of safety, for purposes of design.

The yield strength in the soft temper is about 5000 psi; in the harder tempers it is about 90 to 95% of the tensile strength. In the tempers O, H12 (¼H), and H14 (½H) the material will bend flat on itself. Typical values of shearing strength and endurance limit are shown in Table 2.

SAE 26—(Type 2 Alloy)

General Data—This alloy normally is available in bars, rods, rolled shapes, and wire. For many years it was the standard aluminum structural alloy, and it was used to a considerable extent in trucks, buses, aircraft, and similar products. It has largely been replaced by SAE 24, 240, and 260 for these structural uses. For forgings formerly made of this alloy, the use of SAE 260 in the T4(W) temper is recommended.

Similar Specifications—SAE 26 is similar to ASTM B 211, Alloy CM41A. The commercial designation for SAE 26 is 17S.

Nominal Composition

Copper	4.0
Manganese	0.5
Magnesium	0.5

Physical Properties—The minimum physical properties of the alloy in the form of bars, rods, and wire in the heat-treated temper T4(T) are given in Table 1. The guaranteed maximum tensile strength of the alloy in the soft temper is 35,000 psi. In the heat-treated T4 condition, its shear strength is about 38,000 psi and its endurance limit (500 million cycles) about 18,000 psi.

TABLE 1—*Minimum Physical Properties of SAE 26*

SECTION	DIAMETER OR DISTANCE ACROSS FLATS	TENSILE STRENGTH, PSI	YIELD STRENGTH, PSI	ELONGATION[a] IN 2 IN., %
Rods, bars, and wire	Up to 0.124	55,000	—	—
	0.125 to 8.000	55,000	32,000	16

[a] The gage length for measurement of elongation is equal to four times the diameter or distance across flats except in sections for which a flat tension-test specimen is used, in which the case the gage lenth is 2 in.

SAE 260—(Type 2 Alloy)

General Data—This alloy is a high-strength composition generally similar to SAE 24 and 26 and was originally developed for use in forgings. It is now commercially available in the form of forgings, rolled or extruded rods, bars and shapes, and clad sheet. It has a good machinability and a good resistance to corrosion, although paint protection is recommended (except for clad sheet) in severely corrosive exposures.

Similar Specifications—SAE 260 is similar to ASTM B 209, Alloy Clad CS41A; to ASTM B 211, B 221, and B 235, Alloy CS41A; and to AMS 4121, 4134, 4135, and 4153. The commercial designation for SAE 260 is 14S.

Nominal Composition

Copper	4.4
Silicon	0.8
Manganese	0.8
Magnesium	0.4

Physical Properties—The minimum properties of the alloy are shown in Table 1.

TABLE 1—*Minimum Properties of SAE 260*

FORM	TEMPER	THICKNESS, IN.	TENSILE STRENGTH, PSI	YIELD STRENGTH, PSI	ELONGATION IN 2 IN., %
Forgings	T4	Up to 4	55,000	30,000	16[a]
	T6	Up to 4	65,000	55,000	10[a]
Extruded rods, bars, shapes	T4	All	50,000	35,000[b]	12
	T6	0.125–0.499	60,000	53,000	7
		0.500–0.749	64,000[b]	58,000[b]	7
		0.750 and over[c]	68,000[b]	60,000[b]	7
Rolled rods, bars, shapes	T4	0.125 and over	55,000	32,000	16
	T6	0.170 and over[d]	65,000	55,000	8
Clad sheet	T3	0.020–0.039	55,000	35,000[e]	14
		0.040–0.249	57,000	36,000[e]	15
	T6	0.020–0.039	63,000	55,000	7
		0.040–0.249	64,000	57,000	8

[a] These elongations apply to specimens cut from separately forged coupons. When tension-test specimens are cut from forgings, with the grain flow substantially parallel with the axis of the test specimen, the minimum elongation shall be 11% for T4 temper and 7% for T6 temper. For specimens in which the grain flow is not substantially parallel to the axis, the elongation shall be as agreed upon.
[b] For material heat-treated or reheat-treated by the user, a somewhat lower value must be expected.
[c] Maximum cross-sectional area 25 sq in.
[d] Maximum cross-sectional area 36 sq in.
[e] Applies to flat sheet; for coiled sheet the minimum is about 2,000 psi lower.

The shearing strength of the alloy in the heat-treated (T4) temper is approximately 38,000 psi and in the heat-treated and aged (T6) temper is approximately 45,000 psi. The endurance limit is approximately 18,000 psi in both tempers.

SAE 270—(Type 2 Alloy)

General Data—This alloy finds its principal usage in the production of forged pistons for high-output gasoline engines and in similar forgings required to retain a relatively high strength at elevated temperatures. SAE 290 is used for similar applications.

Similar Specifications—SAE 270 is similar to AMS 4140. The commercial designation for SAE 270 is 18S.

Nominal Composition

Copper	4.0
Nickel	2.0
Magnesium	0.5

Physical Properties—Forgings in this alloy, up to 4 in. in

thickness and in the T6(T) temper, are manufactured to the following minimum property requirements:

Tensile strength, psi	55,000
Yield strength, psi	40,000
Elongation in 2 in., %	10[a]

[a] This elongation applies to specimens cut from separately forged coupons. When tension-test specimens are cut from forgings with the grain flow substantially parallel to the axis of the test specimen, the minimum elongation shall be 7%. For specimens in which the grain flow is not substantially parallel to the axis, the elongation shall be as agreed upon.

SAE 280—(Type 2 Alloy)

General Data—Because of the readiness with which this alloy can be formed hot, it is used for complicated forgings that cannot be readily produced in SAE 26 or 27, for forgings in which a very high strength is not required, and for impact extrusions.

Similar Specifications—SAE 280 is similar to AMS 4125. The commercial designation for SAE 280 is A51S.

Nominal Composition

Silicon	1.0
Magnesium	0.6
Chromium	0.25

Physical Properties—Forgings of this alloy, up to 4 in. in thickness and in the T6(T) temper, are maufactured to the following minimum property requirements:

Tensile strength, psi	44,000
Yield strength, psi	37,000
Elongation in 2 in. or 4D, %	14[a]

[a] This elongation applies to specimens cut from separately forged coupons. When tension-test specimens are cut from forgings with the grain flow substantially parallel to the axis of the test specimen, the minimum elongation shall be 9%. For specimens in which the grain flow is not substantially parallel to the axis, the elongation shall be as agreed upon.

SAE 281—(Type 2 Alloy)

General Data—This alloy has good physical properties, especially yield strength, and is capable of being formed more severely in the T6 (heat-treated and aged) temper than the other Type 2 alloys. In the quenched temper, even more difficult forming can be done, and the resulting shape can then be artificially aged to produce the T6 (heat-treated and aged) temper. Sheet and plate in this alloy are used in bus and truck construction. This alloy also finds some use in aircraft and aircraft engines in the form of both tubing and sheet. Its good resistance to corrosion makes it attractive for many structural applications where its strength will suffice.

Similar Specifications—SAE 281 is similar to ASTM B 209, B 210, B 211, B 221, B 235, and B 241, Alloy GS11A; and to AMS 4025, 4026, 4027, 4080, 4082, and 4150. The commercial designation for SAE 281 is 61S or R361.

Nominal Composition

Magnesium	1.0
Silicon	0.6
Copper	0.25
Chromium	0.25

Physical Properties—The minimum properties of the alloy are shown in Table 1.

The maximum tensile strength in the soft (O) temper is 22,000 psi. The shearing strength in the quenched T4(W) temper is approximately 24,000 psi and in the heat-treated T6(T) temper is about 30,000 psi. The endurance limit is approximately 13,500 psi in either temper.

TABLE 1—*Minimum Properties of SAE 281*

FORM	TEMPER	TENSILE STRENGTH, PSI	YIELD STRENGTH PSI	ELONGATION IN 2 IN. OR 4D, %
Sheet and plate	T4(W) (quenched)	30,000	16,000	14[a]
	T6(T) (heat-treated)	42,000	35,000	8[a]
Extrusions	T4(W) (quenched)	26,000	16,000	16
	T6(T) (heat-treated)	38,000	35,000	10
Tubing	T4(W) (quenched)	30,000	16,000	14[a]
	T6(T) (heat-treated)	42,000	35,000	8[a]
Rods and bars (hot-finished)	T4(W) (quenched)	30,000	16,000	18
	T6(T) (heat-treated)	42,000	35,000	10

[a] The minimum elongation which may be specified for sheet and plate varies with the thickness, and for tubing varies with the wall thickness and diameter.

SAE 282—(Type 2 Alloy)

General Data—This alloy is similar to SAE 281 in its general characteristics, and for this reason has been largely superseded by it for most applications. SAE 282 is still used in the form of extruded shapes for architectural applications.

Similar Specifications—SAE 282 is similar to ASTM B 221, Alloy GS11B. The commercial designation for SAE 282 is 53S.

Nominal Composition

Magnesium	1.3
Silicon	0.7
Chromium	0.25

Physical Properties—The minimum properties of the alloy in the form of extrusions are given in Table 1.

The maximum tensile strength of O material in all forms and sizes is 19,000 psi. The shearing strength of the alloy in the quenched T4(W) temper is approximately 20,000 psi and in the heat-treated T6(T) temper is about 24,000 psi. The endurance limit in both tempers is approximately 13,000 psi.

TABLE 1—*Minimum Properties of SAE 282*

TEMPER	TENSILE STRENGTH, PSI	YIELD STRENGTH, PSI	ELONGATION IN 2 IN. OR 4D, %
T4(W) (quenched)	25,000	14,000	16
T6(T) (heat-treated)	32,000	25,000	10

SAE 29—(Type 1 Alloy)

General Data—This alloy is available in practically all forms although it is not usually used for rolled structural shapes, forgings, or rivets. This alloy is used where strength and hardness somewhat greater than those of commercially pure aluminum (SAE 25) are required. The forming qualities are only slightly inferior to those of the latter material. Its resistance to corrosion is excellent. It is used in the form of sheets for gasoline tanks for aircraft and for automobile-body panels, although some of the harder alloys are finding increasing use for these purposes.

Similar Specifications—SAE 29 is similar to ASTM B 209,

B 210, B 221, B 235, and B 241, Alloy M1A; and to AMS 4006, 4008, 4065, and 4067. The commercial designation for SAE 29 is 3S.

Nominal Composition

Manganese	1.3

Physical Properties—The minimum properties of this material in the form of sheet are shown in Table 1. Other products have comparable, although not identical properties.

Rods and bars are produced only in the hot-finished and cold-finished conditions, for which the approximate tempers are shown in the table in the SAE General Information on Aluminum Alloys. The properties of the corresponding tempers of sheet can be used, with the usual factors of safety, for purposes of design. The strength of extruded sections varies between the values for the soft and the half-hard tempers, depending on the section, but strengths higher than those of the soft temper cannot be guaranteed.

In the O (soft) temper, the yield strength is about 6,000 psi; in the harder tempers, it is approximately 85 to 90% of the ultimate tensile strength. Typical shearing strength and endurance limit are shown in Table 2.

TABLE 1—*Minimum Properties of SAE 29 Sheet*

GRADE AND TEMPER	TENSILE STRENGTH, PSI	PER CENT ELONGATION[a] IN 2 IN., FOR VARIOUS THICKNESSES						
		0.249 to 0.162 in.	0.161 to 0.114 in.	113 to 051 in.	0.050 to 0.032 in.	0.031 to 0.020 in.	0.019 to 0.013 in.	0.012 to 0.008 in.
O (soft)	19,000[b]	25	25	25	23	20	20	18
H12 (¼ hard)	17,000	8	7	6	5	4	3	—
H14 (½ hard)	19,500	7	6	5	4	3	2	1
H16 (¾ hard)	24,000	—	4	4	3	2	1	1
H18 (hard)	27,000	—	4	4	3	2	1	1

[a] In the H12(¼H) and H14(½H) tempers, the tension-test specimen is taken parallel to the direction of rolling.
[b] Maximum. So specified to insure complete annealing.

TABLE 2—*Typical Shearing Strength and Endurance Limit of SAE 29*

TEMPER	APPROXIMATE SHEARING STRENGTH, PSI	APPROXIMATE ENDURANCE LIMIT, PSI
O (soft)	11,000	7,000
H12 (¼ hard)	12,000	8,000
H14 (½ hard)	14,000	9,000
H16 (¾ hard)	15,000	9,500
H18 (hard)	16,000	10,000

SAE 290—(Type 2 Alloy)

General Data—This alloy retains its properties well at elevated temperatures and has a lower coefficient of thermal expansion than the other wrought aluminum alloys. For these reasons, it is well suited for forged pistons.

Similar Specifications—SAE 290 is similar to AMS 4145. The commercial designation for SAE 290 is 32S.

Nominal Composition

Silicon	12.2
Magnesium	1.1
Copper	0.9
Nickel	0.9

Physical Properties—Forgings of this alloy, up to 4 in. in thickness and in the T6(T) temper, are manufactured to the following minimum property requirements:

Tensile strength, psi	52,000
Yield strength, psi	42,000
Elongation in 2 in. or in 4D, %	5[a]

[a] This elongation applies to specimens cut from separately forged coupons. When tension-test specimens are cut from forgings with the grain flow substantially parallel to the axis of the test specimen, the minimum elongation shall be 3.5%. For specimens in which the grain flow is not substantially parallel to the axis, the elongation shall be as agreed upon.

The shearing strength of the alloy is approximately 38,000 psi, and the endurance limit approximately 16,000 psi.

Dimensional Tolerances of Wrought Aluminum Alloys

Tables 1 through 5 list the dimensional tolerances to which aluminum alloy products are commercially produced. These tables apply, however, only to those sizes listed by the producer as commercial for the alloy being ordered. For sizes outside of commercial limits, the tolerances shall be as agreed upon by the supplier and purchaser.

TABLE 1a—*Thickness Tolerances (Plus and Minus) for Flat and Coiled Sheet and Plate, SAE 25 and 29*

THICKNESS, IN.	WIDTH, IN.						
	Up to 18, inclusive	Over 18 through 36	Over 36 through 54	Over 54 through 72	Over 72 through 90	Over 90 through 102	Over 102 through 132
3.000 to 2.751	0.090	0.090	0.090	0.090	0.120	0.150	—
2.750 to 2.251	0.075	0.075	0.075	0.075	0.100	0.125	—
2.250 to 1.876	0.060	0.060	0.060	0.060	0.080	0.100	0.100
1.875 to 1.626	0.052	0.052	0.052	0.052	0.070	0.088	0.088
1.625 to 1.376	0.045	0.045	0.045	0.045	0.060	0.075	0.075
1.375 to 1.126	0.040	0.040	0.040	0.040	0.052	0.065	0.065
1.125 to 0.876	0.035	0.035	0.035	0.035	0.045	0.055	0.055
0.875 to 0.626	0.030	0.030	0.030	0.030	0.037	0.045	0.045
0.625 to 0.439	0.025	0.025	0.025	0.025	0.030	0.035	0.035
0.438 to 0.321	0.019	0.019	0.019	0.019	0.023	0.026	0.026
0.320 to 0.250	0.013	0.013	0.013	0.015	0.017	0.020	—
0.249 to 0.204	0.009	0.009	0.011	0.013	0.015	0.017	—
0.203 to 0.173	0.007	0.007	0.009	0.011	0.013	0.015	—
0.172 to 0.141	0.006	0.006	0.008	0.009	0.011	0.012	—
0.140 to 0.109	0.0045	0.0045	0.005	0.007	0.009	0.010	—
0.108 to 0.097	0.0035	0.004	0.005	0.007	0.009	0.010	—
0.096 to 0.077	0.003	0.003	0.004	0.006	0.008	—	—
0.076 to 0.069	0.0025	0.003	0.004	0.006	0.008	—	—
0.068 to 0.046	0.0025	0.003	0.004	0.005	0.007	—	—
0.045 to 0.037	0.002	0.0025	0.003	0.004	—	—	—
0.036 to 0.029	0.002	0.002	0.0025	0.0035	—	—	—
0.028 to 0.018	0.0015	0.002	0.0025	—	—	—	—
0.017 to 0.011	0.0015	0.0015	0.002	—	—	—	—
0.010 to 0.008	0.001	0.0015	—	—	—	—	—
0.007 to 0.006	0.001	0.001	—	—	—	—	—

TABLE 1b—*Thickness Tolerances (Plus and Minus) for Flat and Coiled Sheet and Plate, SAE 20, 24, 201, 240, and 281*

THICKNESS, IN.	WIDTH, IN.											
	Up to 18, inclusive	Over 18 through 36	Over 36 through 48	Over 48 through 54	Over 54 through 60	Over 60 through 66	Over 66 through 72	Over 72 through 78	Over 78 through 84	Over 84 through 90	Over 90 through 96	Over 96 through 120
3.000 to 2.751	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.120	0.120	—	—	—
2.750 to 2.251	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.100	0.100	0.100	—	—
2.250 to 1.876	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.080	0.080	0.080	0.100	0.100
1.875 to 1.626	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.070	0.070	0.070	0.088	0.088
1.625 to 1.376	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.060	0.060	0.060	0.075	0.075
1.375 to 1.126	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.052	0.052	0.052	0.065	0.065
1.125 to 0.876	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.045	0.045	0.045	0.055	0.055
0.875 to 0.626	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.037	0.037	0.037	0.045	0.045
0.625 to 0.439	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.030	0.030	0.030	0.035	0.035
0.438 to 0.321	0.019	0.019	0.019	0.019	0.020	0.020	0.023	0.023	0.025	0.025	0.026	—
0.320 to 0.250	0.013	0.013	0.013	0.013	0.015	0.018	0.020	0.020	0.020	0.020	—	—
0.249 to 0.204	0.009	0.009	0.011	0.011	0.013	0.016	0.018	0.018	0.018	0.018	0.024	0.028
0.203 to 0.173	0.007	0.007	0.010	0.010	0.011	0.014	0.016	0.017	0.017	0.017	0.022	0.026
0.172 to 0.141	0.006	0.006	0.008	0.008	0.009	0.012	0.014	0.015	0.016	0.017	0.019	0.023
0.140 to 0.109	0.0045	0.0045	0.005	0.005	0.007	0.010	0.012	0.013	0.014	0.016	0.018	0.020
0.108 to 0.097	0.004	0.004	0.005	0.005	0.007	0.010	0.012	0.013	0.014	0.016	0.018	0.020
0.096 to 0.077	0.0035	0.0035	0.004	0.005	0.006	0.008	0.010	0.010	0.011	0.012	—	—
0.076 to 0.069	0.003	0.003	0.004	0.005	0.006	0.008	0.010	0.010	0.011	0.012	—	—
0.068 to 0.046	0.0025	0.003	0.004	0.005	0.006	0.006	0.007	0.008	0.009	—	—	—
0.045 to 0.037	0.002	0.0025	0.003	0.004	0.005	—	—	—	—	—	—	—
0.036 to 0.029	0.002	0.002	0.0025	—	—	—	—	—	—	—	—	—
0.028 to 0.018	0.0015	0.002	0.0025	—	—	—	—	—	—	—	—	
0.017 to 0.011	0.0015	0.0015	—	—	—	—	—	—	—	—	—	
0.010 to 0.007	0.001	0.0015	—	—	—	—	—	—	—	—	—	

Tolerances for Bars, Rods, and Wire—Bars, rods, and wire in all alloys are manufactured to the tolerances shown in Tables 2a to 2c.

TABLE 2a—*Hot-Finished Round Rods, All Alloys*

DIAMETER, IN.	TOLERANCE, IN.	
	Plus	Minus
1.501 to 2.000	0.006	0.006
2.001 to 3.499	0.008	0.008
3.500 to 5.000	1/32	1/64
5.001 to 8.000	1/16	1/32

TABLE 2b—*Hot-Finished Bars, Squares, Hexagons,*[a] *and Rectangles, All Alloys*

LEAST DISTANCE ACROSS FLATS, IN.	TOLERANCE, PLUS AND MINUS	WIDTH OF RECTANGLES, IN.	TOLERANCE, PLUS AND MINUS
Up to 0.500	0.006	Up to 1.500	1/64
0.501 to 0.750	0.008	1.501 to 4.000	1/32
0.751 to 1.000	0.012	4.001 to 6.000	3/64
1.001 to 2.000	0.016	6.001 to 10.000	1/16
2.001 to 4.000	0.020	—	—

[a] Hot finished hexagons are furnished only in sizes over 1½ in.; smaller sizes are cold finished.

TABLE 2c—*Cold-Finished Rods and Bars, Rounds, Squares, Hexagons, Octagons, and Rectangles Up to 4.00 In. Wide or 1½ In. Thick*

DIAMETER OR DISTANCE ACROSS FLATS, IN.	TOLERANCE, PLUS AND MINUS		
	Rounds	Squares, Hexagons, and Octagons	Rectangles
Up to 0.035	0.0005	—	0.0010
0.036 to 0.064	0.0010	0.0015	0.0015
0.065 to 0.500	0.0015	0.0020	0.0020
0.501 to 1.000	0.0020	0.0025	0.0025
1.001 to 1.500	0.0025	0.0030	0.0030
1.501 to 2.000	0.0040	0.0050[a]	0.0050
2.001 to 3.000	0.0040	—	0.0050
3.001 to 4.000	—	—	0.0050

[a] Hexagons only.

Tolerances for Hot-Rolled Structural Shapes—Hot-rolled structural shapes are manufactured to the tolerances shown in Table 3. Standard extruded structural shapes, channels, I-beams, angles, X's, and T's, in which the thickness of web, flange, or leg is not less than 0.140 in. are manufactured to a tolerance of plus and minus 2½% on the nominal weight of the section. Other tolerances on extruded shapes are as agreed upon between the producer and the supplier for the individual section.

(*Continued on next page.*)

TABLE 3—*Hot-Rolled Shapes (Channels, Angles, and Z-Bars)*

	TYPE OF SECTION	TOLERANCE
Thickness of Section	Angles and Z-bars up to 6 x 6 in. Channels up to 10 in.	Up to 0.399 in. inclusive, plus and minus 0.010 in.; 0.400 in. and over, plus and minus 2.5% of the nominal thickness.
Overall Dimensions	Angles and Z-bars up to 6 x 6 in. Channels up to 10 in.	Length of leg, plus and minus 2½% of nominal length, except no tolerance shall be less than plus and minus 1/16 in. Overall width, plus 3/32, minus 1/16 in. Width of flange, plus and minus 4% of nominal width.
Weight	Angles and Z-bars, 3 x 3 in. to 6 x 6 in. Channels, 3 in. up to 10 in.	For a single lot or shipment, plus and minus 2½% of the nominal weight.

Tolerances on Drawn Tubing—Drawn tubing is manufactured to the tolerances shown in Tables 4a to 4c.

TABLE 4a—*Outside-Diameter Tolerances*[a]

NOMINAL DIAMETER, IN.	TOLERANCE
3/32 to ½ inclusive	±0.003
Greater than ½ and up to 1 inclusive	±0.004
Greater than 1 and up to 2 inclusive	±0.005
Greater than 2 and up to 3 inclusive	±0.006
Greater than 3 and up to 5 inclusive	±0.008
Greater than 5 and up to 6 inclusive	±0.010
Greater than 6 and up to 8 inclusive	±0.015
Greater than 8 and up to 10 inclusive	±0.020
Streamline—Major axis	+0.050, −0.035
Minor axis	+0.035, −0.025

[a] For Type 1 alloys the tolerances apply to individual readings of the diameter. For Type 2 alloys the tolerances on round tubes apply to the pi-tape reading or to the mean of two measurements of the diameter taken at right angles to each other in any plane along the length of the tube; individual readings may deviate from the nominal by double these tolerances. These tolerances do not apply to tubes in the O (soft) temper or tubes in which the wall thickness is either less than 2.5% of the outside diameter, or less than 0.020 in.

TABLE 4b—*Wall-Thickness Tolerances*[a]

NOMINAL THICKNESS, IN.	TOLERANCE, PLUS AND MINUS
0.010 to 0.035 inclusive	0.002
0.036 to 0.049 inclusive	0.003
0.050 to 0.120 inclusive	0.004
0.121 to 0.203 inclusive	0.005
0.204 to 0.300 inclusive	0.008
0.301 to 0.375 inclusive	0.012
0.376 to 0.500 inclusive	0.032

[a] For Type 1 alloys the tolerances apply to individual readings of wall thickness. For Type 2 alloys the mean of any two readings of the wall thickness taken 180 deg apart on any diameter of the tube shall not deviate from the nominal thickness by more than the amount of the tolerance shown; individual readings of the wall thickness shall not deviate by more than plus and minus 10% of the nominal thickness

TABLE 4c—*Straightness Tolerances*

NOMINAL OUTSIDE DIAMETER, IN.	ALL ALLOYS AND ALL TEMPERS EXCEPT SOFT[a]
3/8 to 12 inclusive	0.1 in. in 10 ft or 1 part in 1200 parts of length for shorter lengths

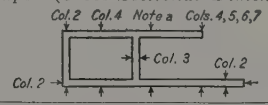
[a] Tubing in O (soft) temper or in diameters less than ¾ in. is supplied commercially straight, substantially free from kinks and sharp bends.

TABLE 5a—*Straightness Tolerances for Extruded Rods, Bars, and Shapes*

CIRCUMSCRIBED CIRCLE DIAMETER, IN.[a]	MINIMUM THICKNESS, IN.	TOLERANCE,[b] IN.
		Allowable deviation from straight per ft of length
1½ and over	—	0.0125
Under 1½	Over 0.094	0.0125
Under 1½	0.094 or under	0.050[c]

[a] The circumscribed circle diameter is the diameter of the smallest circle which will completely enclose the shape.
[b] Not applicable to extruded shapes in the O (annealed) temper.
[c] When weight of shape on flat surface minimizes deviation.

TABLE 5b—*Tolerances (Plus and Minus) for Extruded Rods, Bars, and Shapes (Cross-Sectional Dimensions)*



SPECIFIED DIMENSION, IN.	TOLERANCE,[a] IN.					
	Metal dimensions		Space dimensions			
	Allowable deviation from specified dimension where 75% or more of the dimension is metal		Allowable deviation from specified dimension where more than 25% of the dimension is space[b]			
	All excepting those covered by column 3	Wall thickness[c] completely enclosing space 0.11 sq in. and over (eccentricity)	At dimensioned points ¼ in. to (not including) ⅝ in. from base of leg	At dimensioned points ⅝ in. to (not including) 1¼ in. from base of leg	At dimensioned points 1¼ in. to (not including) 2½ in. from base of leg	At dimensioned points 2½ in. or more from base of leg
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
14 to 15	±0.080		±0.090	±0.106	±0.142	±0.196
12 to 14	±0.074		±0.084	±0.100	±0.134	±0.184
10 to 12	±0.064		±0.074	±0.088	±0.116	±0.160
8 to 10	±0.054		±0.064	±0.074	±0.100	±0.136
6 to 8	±0.044		±0.054	±0.062	±0.082	±0.112
4 to 6	±0.034	Plus or	±0.042	±0.050	±0.064	±0.088
2 to 4	±0.024	minus 10%	±0.032	±0.036	±0.048	±0.064
		max. ±0.060				
1.5 to 2	±0.016	min. ±0.010	±0.024	±0.028	±0.034	±0.050
1 to 1.5	±0.012		±0.020	±0.022	±0.026	±0.034
0.75 to 1	±0.010		±0.018	±0.020	±0.022	±0.030
0.5 to 0.75	±0.009		±0.016	±0.018	±0.020	±0.026
0.25 to 0.5	±0.008		±0.014	±0.016	±0.018	±0.022
0.125 to 0.25	±0.007		±0.012	±0.014	±0.016	±0.020
Under 0.125	±0.006		±0.010	±0.012	±0.014	±0.016

[a] The sum of the tolerances of component dimensions will not be used as a tolerance for an overall dimension.
[b] At points less than ¼ in. from base of leg, the tolerances in Col. 2 are applicable. Where the space is completely enclosed (hollow shapes), the tolerances in Col. 4 are applicable.
[c] Where the dimensions specified are outside and inside, rather than the wall thickness itself, allowable deviation is plus or minus 10% of mean wall thickness, maximum ±0.060, minimum ±0.010.

Magnesium Alloys

SAE General Information

Report of Nonferrous Metals Division approved January 1940 and last revised by Nonferrous Metals Technical Committee January 1950.

Sources of Magnesium—Magnesium is the third most abundant structural element in the earth's crust, and the raw materials from which it can be obtained commercially are widely distributed and may be considered inexhaustible. These sources are sea water, natural brines, and the common minerals magnesite and dolomite. Efficient methods of extracting magnesium have been worked out, the method most commonly used being a process in which sea water is treated with lime to precipitate the magnesium as hydroxide, which is then mixed with hydrochloric acid to produce magnesium chloride solution. This solution is evaporated, and the thoroughly dried magnesium chloride goes to electrolytic cells in which it is broken down into magnesium metal and chlorine gas. Another method of extraction in popular use during World War II was a thermal-reduction method employing an alloy of iron and silicon to reduce magnesium oxide.

Properties—The outstanding characteristic of magnesium and its alloys is lightness, the specific gravity averaging about 1.8. Aluminum, the other light metal, is 50% heavier and the so-called heavy metals—iron, copper, and zinc—are approximately four times as heavy. Magnesium alloys melt at relatively low temperatures, being in the same approximate range as aluminum alloys. Magnesium possesses a relatively high thermal conductivity and coefficient of thermal expansion. The electrical conductivity of magnesium alloys is relatively high; and, like other metals, the conductivity decreases with increasing amounts of alloyed m etals

Alloying Elements—The most common alloying ingredients added to magnesium are aluminum, zinc, and manganese. Small amounts of metals like beryllium, cerium, zirconium, silicon, and tin are sometimes used when it is desired to produce alloys with special properties.

Working and Welding—Magnesium can be readily formed by the common methods known to the metal-working art. These include drawing, pressing, spinning, and bending. The working of magnesium is best done at temperatures of approximately 300 to 750 F[1] because of greatly improved workability and freedom from springback. Magnesium is likewise a very versatile metal with respect to joining operations, because gas, arc, and electric-resistance welding can be used as well as common methods like bolting and riveting.

Corrosion Resistance—The resistance of magnesium to corrosion is such that protective finishes may not be required in rural and most industrial atmospheres, but paint coatings are recommended to prevent tarnishing and roughening of the surface in humid industrial or marine atmospheres. Magnesium is resistant to many alkalis and oils, but generally speaking, it is not recommended for constant contact with water or water solutions. Protective measures have been developed, however, which effectively protect the metal against intermittent contact with water. Working details on magnesium in its various forms are available from the producers of magnesium alloys.

[1] Temperatures near the minimum of the range should be used for hard-rolled sheet, and the time at temperature should be held to the minimum.

When yield strength is specified, it is that stress at which the stress-strain curve deviates 0.2% from the modulus line.

Magnesium Casting Alloys

The magnesium casting alloys listed below are included in the SAE Standard on Magnesium Casting Alloys.

SAE Number	USUAL FORM	GENERAL DATA
50	Sand Cast	General casting alloy
500	Sand Cast	High yield strength, pressure tightness
501	Die Cast	General die-casting alloy
501A	Die Cast	General die-casting alloy
502	Permanent-Mold Cast	Best castability
503	Permanent-Mold Cast	General casting alloy

Magnesium alloys are available as sand castings, die castings and permanent-mold castings. They are furnished in different compositions, depending on the properties required for the intended service. Magnesium castings are used extensively in aircraft, where the metal has replaced heavier materials in engine castings, instrument housings, landing wheels, and miscellaneous structural supports and brackets. Bus and truck applications include tire carriers, transmission housings, and diesel-engine parts. Automotive production applications using cast-magnesium alloys include portable tools, production machinery, foundry patterns, core boxes and flasks, jigs and fixtures, and safety blocks.

The separately cast test specimen serves as a control of the metal quality; and, in the case of heat-treated alloys, it also serves as a control of the heat-treatment process, because such test bars are heat-treated with castings. Factors of safety, used in design, cover the variations of commercial castings from the properties specified for the alloy, which are based on tests of separately cast test specimens.

The properties obtained from test specimens machined from castings will vary, depending upon the location from which the bar is taken. Specimens taken from thin sections may have properties higher than those required for the alloy, while specimens taken from heavy sections or from locations near gates or risers may show lower properties.

When tension-test specimens are to be obtained from castings, not less than 3 and preferably more should be taken. Test bars should be selected in equal numbers from the heaviest, lightest, and intermediate sections of the casting. The specimens may be in the form of flat-sheet specimens or round specimens. The average tensile strength and yield strength of specimens cut from castings shall be not less than 75% of the values shown in the table, and the average elongation shall be not less than 25% of the values.

The physical properties given in the Standard for sand-casting alloys are those obtained from ½ in. diameter standard tension-test specimens separately cast in sand without the use of chills,

while those for permanent-mold alloys are for test bars of similar size cast in a metal mold. These bars are tested without machining after having been subjected to the same heat-treatment as castings.

Sand Castings—In the design of patterns, a shrinkage factor of 5/32 in. per ft is generally used, but this may be reduced to 1/8 in. or less if free shrinkage is restrained by bosses, internal cores, or gates and risers necessary in casting. In order that the best results may be obtained, the casting producer should be consulted concerning the design of patterns, choice of alloy, heat-treatment, and protective measures for the conditions under which the casting is to be used.

Generally, the as-cast condition is used where only moderate strength is required. The heat-treated condition is used for maximum ductility. The heat-treated and aged condition is used for maximum strength and hardness and to minimize growth.

Die Castings—The die-casting process offers many advantages as a method of fabricating magnesium alloys, including low cost in quantity production, decrease in amount of machining, excellent surface finish, dimensional accuracy, and metal saving by virtue of being able to cast thin sections. The cold-chamber process is recommended for die casting magnesium alloys.

Permanent-Mold Castings—Magnesium alloys are available as permanent-mold castings in different compositions, but the majority of permanent-mold castings are produced in compositions SAE 502 and SAE 503. The choice of alloy is frequently controlled by casting-fabrication considerations quite as much as by the physical properties desired. For instance, while it would be desirable to make all permanent-mold castings of SAE 503, because this alloy represents the best combination of mechanical properties, corrosion resistance, and casting characteristics, some parts must be fabricated of composition SAE 502 because it is less hotshort; otherwise, the cost of producing these parts would be prohibitive because of the high scrap loss due to hot cracks. The deciding factor in whether a part should be produced as a sand casting or a permanent-mold casting is usually economy, but complexity of design is also an important factor. While each part must be considered individually, there are instances when quantities as low as 500 pieces can be produced more economically, including cost of mold equipment, as permanent-mold castings than as sand castings, with the added advantage of closer dimensional tolerance. Complex parts which cannot be made in full permanent molds can often be produced in semi-permanent molds using sand cores. By the semi-permanent mold process, fairly complex castings can be produced more economically than in sand, with the advantages of surface smoothness, close tolerance, and the dense structure which characterizes metal cast in chills.

The minimum thickness of section to which magnesium alloys can be cast in the permanent-mold process is approximately 1/8 in. for small areas and 5/32 in. for large areas.

Wrought Magnesium Alloys

The wrought magnesium alloys listed below are included in the SAE Standard on Wrought Magnesium Alloys.

Wrought magnesium alloys are available as extruded bars, rods, shapes, tubing, forgings, rolled plate, and sheet. Magnesium alloys can be given the usual forming operations, such as bending, drawing, pressing, and spinning, but the work must be done hot except for simple operations. Hot working is best done within the temperature range of 300 to 750 F[2] depending on the operation, alloy, and condition. The application of some of the forming processes involve slight changes from present practices with other metals.

SAE Number	USUAL FORMS	GENERAL DATA
51	Sheet and Strip	Maximum formability and weldability
510	Sheet and Strip	Best combination of formability and properties
52	Bars, Rods, Shapes, and Tubing	General extrusions
520	Bars, Rods, Shapes, and Tubing	Intermediate strength
522	Bars, Rods, Shapes, and Tubing	Maximum weldability
523	Bars, Rods, Shapes, and Tubing	Maximum strength
53	Forgings	Hammer forging
531	Forgings	General press forging
532	Forgings	Press forging, highest strength
533	Forgings	Hammer forging, weldable

The purpose of the low composition limits for nickel and iron in the wrought alloys of the magnesium-aluminum-zinc type is to insure corrosion stability. In the case of the magnesium-manganese type alloys, the iron and nickel contents are not so critical but should be maintained as low as possible. Wrought alloys are available in which the iron and nickel are not so closely controlled, and such alloys are suitable for applications where resistance to corrosion is of secondary importance.

Extrusion Alloys—Magnesium alloys can be extruded in standard shapes, such as angles, channels, and I-beams, and in a wide variety of special shapes. Because of the good machinability of magnesium alloys, extruded bars make excellent stock for screw-machine parts. Extruded bars also are used for stock in the making of press or hammer forgings.

SAE 522 is used for applications requiring maximum weldability. SAE 52 is used when a good combination of mechanical properties and formability is required. SAE 520 is intermediate in properties and formability to SAE 52 and SAE 523. SAE 523 in the heat-treated and aged condition has the highest mechanical properties.

Rolled Alloys—Magnesium-alloy sheet is rolled metal up to 0.249 in. in thickness. Plate is rolled metal 0.250 in. and over in thickness. Coiled sheet is available, but the manufacturer should be consulted for maximum gages and sizes available. Magnesium alloy sheet can be supplied in the hard-rolled or annealed conditions. Plate is generally supplied in the hot-finished condition. Plate may be available in the cold-finished condition, but the manufacturer should be consulted on the requirements for surface, flatness, and physical properties. The physical properties of the hot-finished condition may be anywhere between those of

[2] Temperatures near the minimum of the range should be used for hard-rolled sheet, and the time at temperature should be held to the minimum.

the annealed and of the cold-finished conditions but are usually similar to the annealed condition.

Sheet and plate are supplied with either oiled or chrome-pickle surface treatment.

Forgings—Magnesium alloys are available as both hammer forgings and press forgings. The stronger alloys are too tender at hot-working temperature to stand the shock of hammer forging and must be worked slowly under hydraulic presses. They may be forged sometimes to advantage by first pressing to shape and finishing on the hammer.

Die equipment built for aluminum-alloy forgings can, in many cases, be used without change for producing magnesium-alloy hammer forgings. This also applies to small die forgings made by pressing. Large press forgings comparable in size to an aircraft radial-motor crankcase require special equipment and can usually be supplied only as oversize die forgings. Compared with an aluminum forging, magnesium press forgings frequently require an extra blocking die. Hammer forgings are generally more readily procurable than press forgings.

Forgings subject to shock, vibration, or repeated stresses must be carefully designed and carefully machined to avoid notches, sharp corners, tool marks, and other stress raisers. Minimum machining radius is 0.040 in., and all sharp corners and feather edges must be broken. Magnesium-alloy forgings may have marked directional properties, especially with regard to yield strength in tension and in compression. For this reason it is advisable for the user to consult with the manufacturer on the design of forgings.

Magnesium-alloy forgings are normally supplied with a chrome-pickle surface treatment.

Magnesium Casting Alloys

SAE Standard

Report of Nonferrous Metals Division approved January 1940 and last revised by Nonferrous Metals Technical Committee January 1951.

TABLE 1—*Compositions*[a] *of Magnesium Casting Alloys*

SAE No.	ELEMENTS, %					
	Al	Minimum Mn	Zn	Maximum Si	Maximum Cu	Maximum Ni
50	5.3–6.7	0.15	2.5–3.5	0.3	0.25	0.01
500	8.3–9.7	0.10	1.6–2.4	0.3	0.25	0.01
501	8.3–9.7	0.13	0.4–1.0	0.5	0.10	0.01
501A	8.3–9.7	0.13	0.4–1.0	0.5	0.30	0.01
502	9.3–10.7	0.10	0.3 max	0.3	0.10	0.01
503	8.3–9.7	0.10	1.6–2.4	0.3	0.25	0.01

[a] Other elements than those shown total 0.3% maximum. Magnesium is remainder

SAE 50 and 500—(Sand Castings)

General Data—SAE 50 is used for most commercial applications. SAE 500 is used particularly where maximum pressure tightness is required. For application in which the temperature is above 150 to 200 F, the heat-treated and aged condition is used to minimize growth. The properties of SAE 500 are such that it is most advantageously used in the heat-treated and aged condition.

Similar Specifications—SAE 50 is similar to ASTM B 80, Alloy AZ63; and to AMS 4420, 4422, and 4424. SAE 500 is similar to ASTM B 80, Alloy AZ92; and to AMS 4430 and 4434.

Nominal Composition

	SAE 50	SAE 500
Aluminum	6.0	9.0
Zinc	3.0	2.0

Physical Properties—The minimum properties shall be as follows:

	SAE 50	SAE 500
As Cast		
Tensile strength, psi	24,000	20,000
Elongation in 2 in., %	4	—
Heat-Treated		
Tensile strength, psi	34,000	34,000
Elongation in 2 in., %	7	6
Heat-Treated and Aged		
Tensile strength, psi	34,000	34,000
Yield strength, psi	16,000	18,000
Elongation in 2 in., %	3	1

SAE 501 and 501A—(Die Castings)

General Data—The applications for magnesium-alloy die castings in the aircraft, automobile, and other automotive industries are numerous and varied. Rocker-box covers, shroud-tube fittings,

instrument parts, generator and starter-motor parts, and housings of various kinds are examples of some applications. For most applications, these alloys may be considered equivalent, with alloy SAE 501A somewhat less costly and more readily available. Alloy SAE 501 shows somewhat better resistance to corrosion by salt water.

Similar Specifications—SAE 501 and 501A are similar to ASTM B 94, Alloy AZ91; and to AMS 4490.

Nominal Composition

Aluminum	9.0
Zinc	0.7

Physical Properties—The properties shown below are typical of separately cast-to-shape die-cast bars. No minimum properties are required of die castings.

Tensile strength, as-cast, psi	33,000
Yield strength, psi	22,000
Elongation in 2 in., %	3

SAE 502 and 503—(Permanent-Mold Castings)

General Data—The two alloys, SAE 502 and 503, are available in the as-cast, the solution heat-treated, and the heat-treated and aged conditions. The same general remarks apply for the selection of condition as given under sand castings.

Similar Specifications—SAE 502 is similar to ASTM B 199, Alloy A10. SAE 503 is similar to ASTM B 199, Alloy AZ92; and to AMS 4484.

Nominal Composition

	SAE 502	SAE 503
Aluminum	10.0	9.0
Zinc	—	2.0

Physical Properties—Test specimens separately cast in permanent mold and tested without machining after having been subjected to the same heat-treatment as the castings shall have the following minimum properties:

	SAE 502	SAE 503
As Cast		
Tensile strength, psi	20,000	20,000
Heat-Treated		
Tensile strength, psi	34,000	34,000
Elongation in 2 in., %	6	6
Heat-Treated and Aged		
Tensile strength, psi	34,000	34,000
Yield strength, psi	17,000	18,000

Wrought Magnesium Alloys

SAE Standard

Report of Nonferrous Metals Division approved January 1940 and last revised by Nonferrous Metals Technical Committee January 1950.

TABLE 1—*Compositions*[a] *of Wrought Magnesium Alloys*

SAE No.	ELEMENTS, %								
	Al	Minimum Mn	Zn	Maximum Si	Maximum Cu	Maximum Ni	Maximum Fe	Sn	Maximum Ca
51	—	1.2	—	0.3	0.05	0.01	—	—	0.3
510	2.5–3.5	0.2	0.6–1.4	0.3	0.05	0.005	0.005	—	0.3
52	2.5–3.5	0.2	0.6–1.4	0.3	0.05	0.005	0.005	—	—
520	5.8–7.2	0.15	0.4–1.5	0.3	0.05	0.005	0.005	—	—
522	—	1.2	—	0.3	0.05	0.01	—	—	0.3
523	7.8–9.2	0.12	0.2–0.8	0.3	0.05	0.005	0.005	—	—
53	3.0–4.0	0.2	0.3 max	0.3	0.05	0.03	—	4.0–6.0	—
531	5.8–7.2	0.15	0.4–1.5	0.3	0.05	0.005	0.005	—	—
532	7.8–9.2	0.12	0.2–0.8	0.3	0.05	0.005	0.005	—	—
533	—	1.2	—	0.3	0.05	0.01	—	—	0.3

[a] Other elements than those shown total 0.3% maximum. Magnesium is remainder.

SAE 51 and 510—(Sheet Alloys)

General Data—SAE 51 is used in the annealed temper for applications requiring maximum formability, such as aircraft tanks and wheel fairings. It can be readily welded. SAE 510 is used where a combination of good physical properties and best cold-forming characteristics are required. The welding characteristics are inferior to SAE 51. Where salt-water resistance is not required in this material, the iron and nickel may be held at higher limits.

Similar Specifications—SAE 51 is similar to ASTM B 90, Alloy M1; and to AMS 4370. SAE 510 is similar to ASTM B 90, Alloy AZ31X; and to AMS 4375.

Nominal Composition

	SAE 51	SAE 510
Aluminum	—	3.0
Zinc	—	1.0
Manganese	1.5	—

Physical Properties—The minimum properties required for SAE 51 and 510 apply to hard-rolled and annealed sheet from 0.020-in. to 0.249-in. thick. The physical properties of the hot-finished condition may be anywhere between those of the annealed and cold-finished conditions but are usually similar to the

annealed condition. Tests are not required for sheet, strip, and plate thinner or thicker than this.

	SAE 51	SAE 510
Cold Finished		
Tensile strength, psi	32,000	39,000
Yield strength, psi	22,000	29,000
Elongation in 2 in., %	3	4
Annealed		
Tensile strength, psi, maximum	38,000	40,000
Elongation in 2 in., %	12	12

The properties are to be determined on specimens cut parallel with the longitudinal direction or the direction of rolling.

SAE 52, 520, 522, and 523—(Extrusion Alloys)

General Data—SAE 52 is used when a good combination of physical properties and formability is required. SAE 520 has good strength. SAE 522 is used for applications requiring maximum weldability. SAE 523 in the heat-treated and aged condition has the highest strength.

Similar Specifications—SAE 52 is similar to ASTM B 107, Alloy AZ31X; and to ASTM B 217, Alloy AZ31X. SAE 520 is similar to ASTM B 107, Alloy AZ61X; to ASTM B 217, Alloy AZ61X; and to AMS 4350. SAE 522 is similar to ASTM B 107, Alloy M1; and to ASTM B 217, Alloy M1. SAE 523 is similar to ASTM B 107, Alloy AZ80X; and to ASTM B 217, Alloy AZ80X.

Nominal Composition

	SAE 52	SAE 520	SAE 522	SAE 523
Aluminum	3.0	6.5	—	8.5
Zinc	1.0	1.0	—	0.5
Manganese	—	—	1.5	—

TABLE 1—*Minimum Properties of SAE 52, 520, 522, and 523*

	SAE 52	SAE 520	SAE 522	SAE 523	SAE 523[a]	SAE 523[b]
EXTRUDED BARS AND STRUCTURAL SHAPES, DIAM. OR THICK.						
0.249 in. and under						
Tensile strength, psi	33,000	38,000	30,000	43,000	—	47,000
Yield strength, psi	20,000	20,000	—	28,000	—	30,000
Elongation in 2 in., %	7	8	2	9	—	4
0.250 to 1.499 in.						
Tensile strength, psi	32,000	39,000	30,000	43,000	45,000	47,000
Yield strength, psi	20,000	24,000	—	28,000	30,000	32,000
Elongation in 2 in., %	7	9	3	8	5	3
1.500 to 2.499 in.						
Tensile strength, psi	32,000	39,000	30,000	43,000	—	47,000
Yield strength, psi	20,000	24,000	—	28,000	—	32,000
Elongation in 2 in., %	7	9	2	6	—	2
TUBING						
Tensile strength, psi	34,000	36,000	28,000	—	—	—
Yield strength, psi	16,000	16,000	—	—	—	—
Elongation in 2 in., %	8	7	2	—	—	—

[a] Extruded and aged.
[b] Heat-treated and aged.

Physical Properties—Minimum properties are shown in Table 1. Hollow shapes are subject to the physical properties of tubing but to the dimensional tolerances of shapes. The manufacturer should be consulted on allowables for some unusual shapes which cannot be produced to the above specifications.

SAE 53, 531, 532, and 533—(Forging Alloys)

General Data—Two hammer forging alloys are available in SAE 53 and 533. The former has somewhat better physical properties, but the latter may be readily welded. SAE 533 may also be press forged. Hammer forgings are normally more economical than press forgings but can only be used for applications involving moderate stresses. The press-forging alloys SAE 531 and 532 are used in applications involving higher stresses. SAE 532 is stronger than SAE 531, but more difficult to forge, and is usually employed only for comparatively simple forgings requiring highest physical properties. Both SAE 531 and 532 are high-purity alloys with resistance to salt-water corrosion better than that of SAE 53. From the standpoint of economy, SAE 531 is next choice to SAE 53 or 533.

Similar Specifications—SAE 53 is similar to ASTM B 91, Alloy TA54. SAE 531 is similar to ASTM B 91, Alloy AZ61X; and to AMS 4358. SAE 532 is similar to ASTM B 91, Alloy AZ80X; and to AMS 4360. SAE 533 is similar to ASTM B 91, Alloy M1.

Nominal Composition

	SAE 53	SAE 531	SAE 532	SAE 533
Aluminum	3.5	6.5	8.5	—
Zinc	—	1.0	0.5	—
Manganese	—	—	—	1.5
Tin	5.0	—	—	—

Physical Properties—The properties for forgings are those obtained from tension-test specimens taken with the longitudinal axis parallel to the direction of maximum flow of the metal. In the case of forgings, from which specimens cannot be taken in this manner, the test specimen is taken from test coupons separately forged from the stock from which the forgings are made. The minimum properties shall be as follows:

	SAE 53	SAE 531	SAE 532	SAE 533
As-Forged				
Tensile strength, psi	36,000	38,000	42,000	30,000
Yield strength, psi	22,000	22,000	26,000	18,000
Elongation in 2 in., %	7	6	5	3

Dimensional Tolerances of Wrought Magnesium Alloys

Tables 1 through 6 list the dimensional tolerances to which wrought magnesium-alloy products are commercially produced. These tables apply, however, only to those sizes listed by the producer as commercial for the alloy being ordered. For sizes outside of commercial limits, the tolerances shall be as agreed upon by the supplier and purchaser.

(*Continued on next page.*)

TABLE 1—*Thickness Tolerances for Plate, Sheet, and Strip*

THICKNESS, IN.	TOLERANCE, IN., PLUS AND MINUS	
	Under 36 in. wide	36 in. to 50 in. wide
0.015–0.036	0.002	0.0025
0.037–0.050	0.0025	0.003
0.051–0.080	0.003	0.004
0.081–0.250	5% of sheet thickness	5% of sheet thickness
0.251–0.500	4% of sheet thickness	4% of sheet thickness
0.501–1.000	3% of sheet thickness	3% of sheet thickness

TABLE 2—*Width Tolerances for Plate, Sheet, and Strip*

THICKNESS, IN.	TOLERANCE, IN., PLUS AND MINUS		
	18 in. wide and under	Over 18 in. to 36 in. wide	36 in. to 50 in. wide
0.015–0.102	1/16	3/32	1/8
0.103–0.250	3/32	1/8	3/16
0.251–0.500	1/8	5/32	3/16
0.501–1.000	1/4	1/4	1/4

TABLE 3—*Length Tolerances for Plate, Sheet, and Strip*

THICKNESS, IN.	TOLERANCE, IN., PLUS AND MINUS			
	18 in. long and under	Over 18 in. to 48 in.	48 in. to 120 in.	120 in. long and over
0.015–0.250	1/16	3/32	1/8	5/32
0.251–0.500	1/8	5/32	3/16	7/32
0.501–1.000	3/8	3/8	3/8	3/8

Tolerance on Wall Thickness of Tubing—The tolerance on the wall thickness will be maintained within plus and minus 10% of the nominal wall thickness with a minimum tolerance of plus and minus 0.010 in.

Tolerance on Camber—The bow (or camber) in sections falling within a 1½-in. diameter circumscribed circle, and in which the predominant thickness is 3/32 in. or less, shall not exceed one part in 240 parts of length (0.050 in. per ft) when the section is lying in such a way that its weight minimizes the bow. For all other sections, it shall not exceed one part in 960 parts of length (0.0125 in. per ft), measured over any 5 ft of length and regardless of how the section is lying on the inspection table. Material ordered in random lengths and tubing less than 3/8 in. in diameter shall be free from kinks and sharp bends and shall be reasonably straight, but shall not be required to conform to the above tolerances.

TABLE 4—*Cross-Sectional Dimension Tolerances*

DIMENSIONS, IN.	TOLERANCE, IN., PLUS AND MINUS EXTRUDED RODS, BARS, AND SHAPES
Up to 0.125	0.010
0.126 to 0.500	0.015
0.501 to 1.000	0.020
1.001 to 2.000	0.025
2.001 to 3.000	0.030
3.001 to 4.000	0.035
4.001 to 5.000	0.040
5.001 to 6.000	0.045
6.001 to 7.000	0.050
7.001 to 8.000	0.055
8.001 to 9.000	0.060
9.001 to 10.000	0.065
10.001 to 11.000	0.070
11.001 to 12.000	0.080

TABLE 5—*Permissible Variations in Tubing Diameter*

DIAMETER, IN.	TOLERANCE, IN., PLUS AND MINUS	
	Allowable deviation of mean diameter[a] from specified diameter	Allowable deviation of diameter at any point from specified diameter[b]
Up to 0.999	0.010	0.020
1.000 to 1.999	0.012	0.025
2.000 to 3.999	0.015	0.030
4.000 to 5.999	0.025	0.050
6.000 to 7.999	0.037	0.075
8.000 to 9.999	0.045	0.100

[a] The mean diameter is determined by the average of two measurements taken at right angles to each other.
[b] Not applicable if the wall thickness is less than 2½% of the outside diameter.

TABLE 6—*Length Tolerances for Rods, Bars, Shapes, and Tubing*

MAXIMUM CROSS-SECTIONAL DIMENSION, IN.	TOLERANCE, IN.	
	Length, 10 ft and under	Length, over 10 ft
Up to 3.0	minus 0, plus 1/8	minus 0, plus 1/4
Over 3.0	minus 0, plus 1/4	minus 0, plus 1/4

Zinc Die-Casting Alloys

SAE General Information

Report of Nonferrous Metals Division approved June 1934 and last revised by Nonferrous Metals Technical Committee January 1950.

Because of the drastic chilling involved in die casting and the fact that the solid solubilities of both aluminum and copper in zinc change with temperature, these alloys are subject to some aging changes, one of which is a dimensional change. All of the alloys undergo a slight shrinkage after casting, which at room temperature is about two-thirds complete in five weeks. It is possible to bring about this shrinkage by a stabilizing anneal, and in the case of SAE 903 and 925 in which no further changes occur after the shrinkage, such an anneal can be used to advantage in some cases. The recommended stabilizing anneal is 3 to 6 hr at 100 C (212 F), or 5 to 10 hr at 85 C (185 F), or 10 to 20 hr at 70 C (158 F). The time in each case is measured from the time at which the castings reach the annealing temperature. The parts may be air cooled after annealing. Such a treatment will cause a shrinkage (0.0004 in. per in.) of about two thirds of the total, and the remaining shrinkage will occur at room temperature during the subsequent few weeks. Stabilizing results in a decrease in dimensions of about 0.0005 in. per in. from the original size of the casting. Stabilizing is, of course, unnecessary if the machining or fitting operations can be delayed until the castings have aged five weeks at room temperature.

In SAE 921, the shrinkage is followed by an expansion which occurs slowly over a period of several years at room temperature. Because this expansion is not affected by a stabilizing anneal, there is no advantage in such an anneal for this alloy.

When exposed to stagnant moisture or condensation with limited access to oxygen, a non-uniform type of corrosion may occur on zinc die castings, which often results in the formation of a bulky film of white corrosion products. This may hinder the operation of such parts as automobile lock cylinders, fuel pumps. and carburetors and in severe cases result in rather rapid loss of zinc. Various types of chromate films are available to overcome this condition.

The same electroplating or enamelling procedure is used with all three alloys. Organic finishes are quite variable in their ability to adhere well to zinc surfaces. The phosphate type of chemical pretreatment has received widest commercial utilization, and most zinc die castings which are to be finished with lacquers or enamels are phosphate pretreated. In general, a much wider selection of finishes can be used on pretreated die castings.

The relative merits of the three SAE alloys may be outlined as follows:

SAE 903—When the shrinkage referred to above has been removed by normal aging or by a stabilizing anneal, the dynamic and dimensional properties of this alloy are permanent at service temperatures up to 100 C (212 F). Castings stabilized at elevated or at room temperature prior to final machining, assembling, or other adjusting of dimensions will permanently maintain such dimensions within a tolerance of plus or minus 0.00025 in. per in. in the absence of excessive moisture. When exposed to high humidity and temperature (as wet steam at atmospheric pressure or humid tropical climates), any change of either properties or dimensions will be only those resulting from surface corrosion analogous to those occurring in any other materials which are not totally resistant to oxidation.

SAE 921—This alloy, used extensively in the past, has been replaced largely by SAE 903 and 925 because these alloys possess greater permanence of properties and dimensions. While SAE 921 is outstanding in hardness and tensile strength, it ages with an appreciable loss of impact strength and dimensional stability. It is still the preferred alloy where resistance to abrasion is particularly important, as in door-lock striker plates and latches.

SAE 925—This alloy is somewhat stronger and harder than SAE 903. At room temperature, it is equal to SAE 903 in permanence of dimensions and impact strength. At elevated temperatures it is subject to growth in dimensions and loss of impact strength and, in this respect, is inferior to SAE 903.

Typical Physical Properties in the As-Cast State at Room Temperature

	SAE 903	SAE 921	SAE 925
Tensile Strength, psi	41,000	52,000	47,000
[a]Impact Strength, ft-lb (¼ x ¼ in. bar)	43	35	47
Elongation in 2 in., %	10	8	7
Transverse Deflection, in.	0.27	0.22	0.16
Compression Strength, psi	60,000	93,000	87,000
Shearing Strength, psi	31,000	46,000	38,000
Electrical Conductivity, mhos per cm³ at 20 C (68 F)	157,000	146,000	153,000
Thermal Conductivity, cal per sec per cm³ per C	0.27	0.25	0.26
Thermal Expansion, in. per in. per C	0.0000274	0.0000277	0.0000274
Thermal Expansion, per F	0.0000152	0.0000154	0.0000152
Specific Gravity	6.6	6.7	6.7
Specific Heat	0.10	0.10	0.10
Brinell Hardness	82	100	91

[a] Impact strength drops rapidly below 32 F to approximately 4 ft-lb at −4 F.

Zinc-Alloy Ingot and Die-Casting Compositions

SAE Standard

Report of Nonferrous Metals Division approved June 1934 and last revised by Nonferrous Metals Technical Committee January 1950.

COMPOSITION,[a] %	SAE 903		SAE 921		SAE 925	
	Ingot	Castings	Ingot	Castings	Ingot	Castings
Al	3.9–4.3	3.5–4.3	3.9–4.3	3.5–4.5	3.9–4.3	3.5–4.3
Cu	0.10	0.10	2.5–2.9	2.5–3.5	0.75–1.25	0.75–1.25
Mg	0.03–0.06	0.03–0.08	0.02–0.05	0.02–0.10	0.03–0.06	0.03–0.08
Fe	0.075	0.10	0.075	0.10	0.075	0.10
Pb	0.005	0.007	0.005	0.007	0.005	0.007
Cd	0.004	0.005	0.004	0.005	0.004	0.005
Sn	0.002	0.005	0.002	0.005	0.002	0.005

[a] Percentages given are maximum except where indicated as a range. Zinc is remainder.

Similar Specifications—SAE 903 is similar to AMS 9803. SAE 903 ingot is similar to ASTM B 240 T, Alloy XXIII; and SAE 903 casting is similar to ASTM B 86-48, Alloy XXIII. SAE 921 ingot is similar to ASTM B 240 T, Alloy XXI; and SAE 921 casting is similar to ASTM B 86-48, Alloy XXI. SAE 925 ingot is similar to ASTM B 240 T, Alloy XXV; and SAE 925 casting is similar to ASTM B 86-48, Alloy XXV.

Corrosion-, Heat-, and Electrical-Resistance Alloys

SAE General Information

Report of Nonferrous Metals Division approved January 1946 and last revised by Nonferrous Metals Technical Committee January 1950.

[*This summary is intended to supply information on nickel and some of its nonferrous alloys which have been used in the automotive industry because of special combinations of chemical, mechanical, and physical properties not available in other nonferrous alloys or in steel. The numerical data describe wrought products principally. For standard alloy compositions for heat- and corrosion-resistant castings, refer to SAE Standard on Permissible Variations from Specified Chemical Ranges and Limits for Steels.*

The average safe working stresses, depending upon creep which can be tolerated, range from 5000 to 10,000 psi at 1200 F, 600 to 2000 psi at 1600 F, and 100 to 300 psi at 2000 F.]

Nickel—This is commercially pure, malleable nickel. Its average nickel content is 99.40%. This includes a few tenths of a per cent of cobalt which is counted as nickel, because its effect upon the significant properties of nickel is not detrimental.

Age-Hardenable Nickel—This is an age-hardenable, high-nickel alloy in which great strength and hardness are added to the high resistance to corrosion that is characteristic of nickel. The alloy has desirable spring characteristics.

Nickel-Manganese; Nickel-Manganese-Silicon—These alloys contain 4 to 5% manganese and up to 1% silicon but otherwise conform chemically to nickel. The manganese imparts resistance to attack by sulfur compounds at elevated temperatures, especially under oxidizing conditions. The alloys have been adopted generally for spark-plug electrodes in internal-combustion engines.

70 Nickel—30 Copper—These alloys have high strength and hardness, good resistance to corrosion, and are used extensively in industry. The age-hardenable alloy contains approximately 2.75% of aluminum and is nonmagnetic at temperatures down to minus 150 F. Its mechanical properties, particularly in large sections, are comparable with those of heat-treated alloy steels. The free-machining alloy is suitable for use in automatic screw machines, its free-machining characteristics being achieved by a sulfur content of approximately 0.035%.

55 Copper—45 Nickel—These alloys are alloys of the constantan type and are used extensively with iron or copper as a thermoelectric element for temperature measurement and control. They are used for resistance purposes at temperatures up to 930 F and up to 1830 F for thermocouple purposes.

77 Copper—23 Nickel; 89 Copper—11 Nickel; 93 Copper—7 Nickel; 97.5 Copper—2.5 Nickel—These alloys are copper-nickel alloys containing decreasing amounts of nickel in the order named. The properties which have been exploited in instru-

ments and controls are the specific resistance and temperature coefficient. These properties are held within very close limits by careful control in melting and fabricating.

70 Nickel—30 Iron—This alloy has some unique electrical properties and a high temperature coefficient of resistance along with a high specific resistance. Uses have been made of it in various panel instruments.

50 Nickel—50 Iron—This alloy has definite expansion characteristics and interesting magnetic properties.

42 Nickel—58 Iron—This alloy is a low-expansion alloy having

TABLE 1—*Nominal Chemical Compositions*

ALLOY GROUPS AND ALLOYS	ELEMENTS, %							
	Nickel[a]	Copper	Chromium	Iron	Manganese	Silicon	Carbon	Other
Nickel								
Nickel	99.4	0.1	—	0.15	0.25	0.05	0.05	—
Age-hardenable nickel	93.7	—	—	0.35	0.3	0.5	0.17	4.4 Al
Nickel-Manganese								
95 Ni—5 Mn	95.2	0.05	—	0.15	4.5	0.05	0.1	—
95 Ni—4 Mn—1 Si	95	—	—	—	4.0	1.0	0.05	—
Nickel-Copper								
70 Ni—30 Cu	67	30	—	1.4	1	0.1	0.15	—
Age-hardenable 70 Ni—30 Cu	66	29	—	0.9	0.75	0.5	0.15	2.75 Al
Free-machining 70 Ni—30 Cu	67	30	—	1.4	1.0	0.05	0.15	0.035 S
Copper-Nickel								
55 Cu—45 Ni	43	55	—	0.25	0.5–1.0	—	0.05	—
77 Cu—23 Ni	23	77	—	—	—	—	—	—
89 Cu—11 Ni	11	89	—	—	—	—	—	—
93 Cu—7 Ni	7	93	—	—	—	—	—	—
97.5 Cu—2.5 Ni	2.5	97.5	—	—	—	—	—	—
Nickel-Chromium								
94 Ni—3 Mn—2 Al—1 Si	94	—	—	—	3	1	—	2 Al
90 Ni—10 Cr	90	—	10	—	—	—	—	—
80 Ni—20 Cr	Remainder	—	20	0.5	0.2–2.0[b]	1.25–1.4	0.06–0.1	—
74 Ni—20 Cr	Remainder	—	19–20	3	—	—	—	3 Al
Nickel-iIron								
70 Ni—30 Fe	70	—	—	29	1	0.05	0.05	—
50 Ni—50 Fe	50	—	—	49	0.1	0.05	0.05	—
42 Ni—58 Fe	42	—	—	58	0.1	0.05	0.05	—
36 Ni—64 Fe	36	—	—	64	0.1	0.05	0.05	—
Nickel-Silicon-Copper								
85 Ni—10 Si—4 Cu	Remainder	3–5	—	—	—	8–10	—	—
Nickel-Molybdenum								
65 Ni—28 Mo	Remainder	—	—	4–7	—	—	0.12[c]	26–30 Mo
Nickel-Molybdenum-Chromium-Tungsten								
55 Ni—17 Mo—16 Cr—4 W	Remainder	—	14–17	4–7	—	—	0.15[c]	15–19 Mo; 3.5–5.5 W
Nickel-Chromium-Iron								
77 Ni—15 Cr	77	0.2	15	7	0.25	0.25	0.6	—
Age-hardenable 73 Ni—15 Cr	73	—	15	7	0.5	0.4	0.04	2.5 Ti; 1 Cb; 0.9 Al
68 to 60 Ni—18 to 15 Cr	68–60	—	18–12	Remainder	0.2–1.35	1.0–1.4	0.06–0.5	—
39 to 35 Ni—18 to 15 Cr	39–35	—	20–15	Remainder	0.1–1.2	1.1–1.5	0.05–0.4	—
12 Ni—24 Cr	12	—	24	Remainder	0.9	1.0	0.3	—

[a] Includes a small amount of cobalt
[b] Depending upon use.
[c] Maximum.

the same expansion as that of some common glasses. It is used for sealing in glass and for bimetal and other controls at somewhat higher temperatures than those for which invar is suitable.

36 Nickel—64 Iron—These alloys are known generally as invar and have the lowest coefficients of any known alloys. They are used extensively for thermostats, precision-instrument parts for

TABLE 2—*Average Physical Constants*

ALLOY GROUPS AND ALLOYS	DENSITY, LB/CU IN.	MELTING POINT, F	THERMAL CONDUCTIVITY, 32 to 212 F, BTU/SQ FT/HR/F/IN.	COEFFICIENT OF THERMAL EXPANSION, IN./IN./F		SPECIFIC HEAT 32 TO 212 F, BTU/LB/F	ELECTRICAL RESISTIVITY, ROOM TEMPERATURE		TEMPERATURE COEFFICIENT OF ELECTRICAL RESISTIVITY		MAGNETIC PROPERTIES		MAXIMUM OPERATING TEMPERATURE IN AIR (SULFUR-FREE) F
				32 to 212 F	32 to 1832 F		ohms/cir. mil ft	microhms/cu cm	68 to 212 F, per F	68 to 1832 F, per F	Condition at room temperature	Curie temperature, F	
Nickel													
Nickel	0.321	2615–2635	420	0.0000072	—	0.13	57	9.5	0.0024	—	magnetic	680	1900 [j]
Age-hardenable nickel	0.316	2615–2635	420	0.0000072	—	0.13	94.5	15.7	0.002	—	magnetic	555–570	—
Nickel-Manganese													
95 Ni—5 Mn	0.317	2600	335	0.0000074	—	0.13	110	18.3	0.002	—	magnetic	555–560	1650 [j]
95 Ni—4 Mn—1 Si	0.315	2600	266	0.0000076	0.0000095	0.092	150	25	0.00139	—	magnetic	—	1380 [j]
Nickel-Copper													
70 Ni—30 Cu	0.319	2370–2460	180	0.0000078	0.0000089	0.13	290	48.2	0.0011	—	slightly magnetic	110–140	1060 [j]
Age-hardenable 70 Ni—30 Cu	0.306	2400–2460	130	0.0000078	0.0000089	0.13	350	58.1	0.0001	—	nonmagnetic	−150	—
Free-machining 70 Ni—30 Cu	0.319	2370–2460	180	0.0000078	—	0.13	290	48.2	0.0011	—	slightly magnetic	110–140	—
Copper-Nickel													
55 Cu—45 Ni	0.320	2210	159	0.0000082	0.0000104	0.094	294	49	0.00001	—	nonmagnetic	—	1830 [k]
77 Cu—23 Ni	0.321	2085	232	0.0000074	0.0000097 [b]	0.092	180	30	0.0001	—	nonmagnetic	—	212 [j]
89 Cu—11 Ni	0.321	2010	267	0.0000097	—	0.092	90	15	0.00025	—	nonmagnetic	—	212 [j]
93 Cu—7 Ni	0.321	2010	261	0.00001	0.00001 [b]	0.092	60	10	0.00039	—	nonmagnetic	—	212 [j]
97.5 Cu—2.5 Ni	0.321	2010	262	0.0000085	—	0.092	30	5	0.0006	—	nonmagnetic	—	212 [j]
Nickel-Chromium													
74 Ni—20 Cr	0.292	2550	99	0.0000055	—	0.104	800	133	0.000011	0.000013 [e]	slightly magnetic	—	302
94 Ni—3 Mn—2 Al—1 Si	0.311	2515	206	0.000012	—	0.125	177	29.4	—	0.0014 [f]	nonmagnetic	—	2300
90 Ni—10 Cr	0.315	2600	133	0.000013	—	0.107	425	70.6	—	0.00032 [f]	nonmagnetic	—	2300
80 Ni—20 Cr	0.304	2550	104	0.0000066–0.0000076 [a]	0.0000095–0.0000098 [a]	0.104–0.107 [a]	650	108	0.000072 [e]	0.000013 [g]	nonmagnetic	—	2100
Nickel-Iron													
70 Ni—30 Fe	0.305	2597	64	0.0000069	0.0000083	0.125	120	20	0.0028	0.0031 [h]	magnetic	—	930
50 Ni—50 Fe	0.298	2600	104	0.0000052	0.0000072	0.115	260	43	0.0017	0.001	magnetic	—	975 [j]
42 Ni—58 Fe	0.293	2600	93	0.0000027	0.0000072 [b]	0.119	400	67	0.0012	0.00052	magnetic	—	705 [j]
36 Ni—64 Fe	0.292	2600	76	0.0000004	0.000008	0.123	484	80	0.00075	—	magnetic	—	390 [j]
Nickel-Silicon													
85 Ni—10 Si—4 Cu	0.282	2375	145	0.000011	0.0000181	0.109	680	113	—	0	nonmagnetic	—	—
Nickel-Molybdenum													
65 Ni—28 Mo	0.334	2410–2460	78.5	0.0000113	0.0000153	0.091	812	135	—	0	slightly magnetic	—	—
Nickel-Molybdenum-Chromium-Tungsten													
5 Ni—17 Mo—16 Cr—4 W	0.323	2320–2380	87	0.00001	0.0000146	0.092	800	133	—	—	slightly magnetic	—	—
Nickel-Chromium-Iron													
77 Ni—15 Cr	0.307	2540–2600	104	0.0000064	0.000009	0.11	590	98.2	—	—	nonmagnetic	−40	2000 [j]
Age-hardenable 73 Ni—15 Cr	0.3	2540–2600	102	0.0000076	0.0000095	0.11	734	122	—	—	nonmagnetic	−280	1500
68 to 60 Ni—18 to 15 Cr	0.296–0.310	2450–2550	94–97	0.0000062–0.0000076 [a]	0.000008–0.00001 [a]	0.106–0.108 [a]	660–675 [a]	110–112 [a]	0.000094–0.00019 [a,d]	0.00006–0.000108 [a,i]	nonmagnetic	—	1700–1950 [a]
39 to 35 Ni—18 to 15 Cr	0.287–0.291	2510–2560	90–94	0.0000074–0.0000077 [a]	0.0000097–0.000017 [a]	0.107–0.118 [a]	600–610 [a]	100–102 [a]	0.00022	0.00014–0.00015 [a]	slightly magnetic-nonmagnetic [a]	—	1400–2100 [a]
12 Ni—24 Cr	0.280	2550	102	0.000008	0.0000097	0.118	510	85	—	—	nonmagnetic	—	2000 [j]

[a] Depends upon chemical composition.
[b] 32 to 1382 F.
[c] 0.0000485 when calculated from rise in resistance of metal which has been cooled slowly; see ASTM B 82 and B 83. 0.000121 when calculated from rise in resistance of metal as received from maker.
[d] 0.000106 when calculated from rise in resistance of metal which has been cooled slowly. 0.000144 when calculated from rise in resistance of metal as received from maker.
[e] 68 to 302 F.
[f] 68 to 1600 F.
[g] 0.0000121 when calculated from rise in resistance of metal which has been cooled slowly. 0.000047 when calculated from rise in resistance of metal as received from maker.
[h] 32 to 932 F.
[i] 0.0000625 when calculated from rise in resistance of metal which has been cooled slowly. 0.000085 when calculated from rise in resistance of metal as received from maker.
[j] Not suitable for use as electrical heating material.
[k] Thermocouple use only at this temperature; 930 F for an electrical heating material.

aeronautical use, for struts in aluminum pistons, and other applications utilizing their lack of expansion.

80 Nickel—20 Chromium—This alloy is an iron-free, nonmagnetic alloy developed especially to give maximum life as electrical heating elements which are expected to stand up under the most adverse conditions up to surface temperatures of 2100 F. Its exceptional resistance to oxidation at elevated temperatures, high electrical resistivity, low temperature coefficient of

TABLE 3—*Ranges of Mechanical Properties*

ALLOY GROUPS AND ALLOYS	AVAILABLE FORMS[a]	YIELD STRENGTH 0.2% OFFSET, 1000 PSI	TENSILE STRENGTH, 1000 PSI	ELONGATION IN 2 IN., %	REDUCTION OF AREA, %	HARDNESS		MODULUS OF ELASTICITY, 10^{-6} PSI	ENDURANCE LIMIT 10^8 CYCLES, 1000 PSI	IMPACT, FT-LB	
						Brinell 3000 kg	Rockwell			Standard Izod	Standard Charpy
Nickel											
Nickel	A,B,C,D,E,F,G	15–155	60–165	50–2	75–50	90–230	40B–100B	30	23–36	120	222–195
Age-hardenable nickel	A,C,E	30–150	90–250	50–2	65–15	140–380	75B–46C	30	52–59	120–25	240–36
Nickel-Manganese											
95 Ni—5 Mn	A,C,E	25–125	75–140	50–2	75–60	110–230	60B–100B	30	—	—	—
95 Ni—4 Mn—1 Si	A,B,C,E	35–160	70–175	35–0.5	75–50	—	80B–15C	—	—	—	—
94 Ni—3 Mn—2 Al—1 Si	C	—	85–170	—	—	—	—	—	—	—	—
Nickel-Copper											
70 Ni—30 Cu	A,B,C,D,E,F,G	25–160[b,c]	70–170	50–2	75–50	110–250	60B–23C	26	30–50	120–75	220–150
Age-hardenable 70 Ni—30 Cu	A,B,C,E,F	40–175[b,d]	90–200	45–2	70–25	140–320	75B–40C	26	41–59	120–26	170–42
Free-machining 70 Ni—30 Cu	A,C	25–130	70–140	50–4	70–50	110–230	60B–100B	26	28–41	120–96	196–140
Copper-Nickel											
55 Cu—45 Ni	A,B,C,E	30–120	60–135	45–0.5	70–25	—	50B–93B	—	—	—	—
77 Cu—23 Ni	A,B,C,E	20–70	40–80	55–2	75–50	—	50B–85B	—	—	—	—
89 Cu—11 Ni	A,B,C,E	20–70	40–80	55–2	75–50	—	50B–85B	—	—	—	—
93 Cu—7 Ni	A,B,C,E	20–70	40–80	55–2	75–50	—	50B–85B	—	—	—	—
97.5 Cu—2.5 Ni	A,B,C,E	20–70	40–80	55–2	75–50	—	50B–85B	—	—	—	—
Nickel-Chromium											
90 Ni—10 Cr	C	—	95–165	—	—	—	—	—	—	—	—
80 Ni—20 Cr	A,B,C,D,E,F,G	50–190	100–200	35–0.5	70–40	150–320	85B–30C	31	—	—	—
Nickel-Iron											
70 Ni—30 Fe	A,B,C,E	35–140	70–150	35–0.5	60–30	—	58B–93B	—	—	—	—
50 Ni—50 Fe	A,B,C,E	35–140	70–150	35–0.5	60–30	—	58B–93B	—	—	—	—
42 Ni—58 Fe	A,B,C,E	35–140	70–150	35–0.5	60–30	—	58B–93B	—	—	—	—
36 Ni—64 Fe	A,B,C,E	35–140	70–150	35–0.5	60–30	—	58B–93B	—	—	—	—
Nickel-Chromium-Iron											
77 Ni—15 Cr	A,B,C,D,E,F,G	25–175	80–185	50–2	70–40	120–290	65B–30C	31	41–60	120–70	230–151
Age-hardenable 73 Ni—15 Cr	A,B,C,D,E,F,G	50–240	110–275	45–2	60–30	200–500	93B–47C	31	45–65	40	—
68 to 60 Ni—18 to 15 Cr	A,B,C,D,E,F,G	40–160	80–175	35–0.5	70–40	120–250	83B–24C	31	—	—	—
39 to 35 Ni—18 to 15 Cr	A,B,C,D,E,F,G	30–140	70–150	35–0.5	70–25	110–260	80B–18C	31	—	—	—
12 Ni—24 Cr	A,C,D,E,F,G	30–50	60–90	22–1	35–25	140–240	—	—	—	—	—
74 Ni—20 Cr	C	50–90	130–180	35–0.5	70–40	—	—	—	—	—	—
Nickel-Silicon											
85 Ni—10 Si—4 Cu	G	—	105–125	1	—	—	46C–49C	—	—	—	—
Nickel-Molybdenum											
65 Ni—28 Mo	A,B,C,D,E,F,G	56–68	130–140	55–35	50–30	155–215	92B–21C	31	—	78–68	62–58
Nickel-Molybdenum-Chromium-Tungsten											
55 Ni—17 Mo—16 Cr—4 W	A,B,C,D,E,F,G	52–63	125–140	48–20	54–20	175–215	92B–22C	28.5	—	40–30	23–21

[a] A—Rods and bars, over ½ in. diameter; B—Forgings; C—Wire, ½ in. diameter maximum; D—Sheet; E—Strip; F—Tubing; G—Castings

[b] Rods and bars.

[c] Yield strength 0.01% offset (proof stress) = 20,000–95,000 psi.

[d] Yield strength 0.01% offset (proof stress) = 70,000–125,000 psi.

resistance, high tensile strength at temperature, and resistance to chemical corrosion have given it a wide variety of applications.

74 Nickel—20 Chromium—This is a special alloy containing approximately 3% of each of iron and aluminum to give a low and uniform coefficient of electrical resistance at temperatures up to 302 F.

90 Nickel—10 Chromium; 94 Nickel—3 Manganese—2 Aluminum—1 Silicon—These alloys are the positive and negative elements, respectively, in standard chromel-alumel thermocouples.

77 Nickel—15 Chromium—This alloy has good resistance to a great variety of corrosive media, to scaling, and to intercrystalline attack at elevated temperatures. It is used extensively for heat-treating, nitriding, and carburizing fixtures.

Age-Hardenable 73 Nickel—15 Chromium—This is an age-hardenable, nickel-chromium alloy which was developed to have maximum strength and resistance to oxidation at temperatures of 1200 to 1500 F for use as parts of gas turbines and heat engines. The alloy has desirable spring characteristics at temperatures up to 1000 F.

68 to 60 Nickel—18 to 15 Chromium—These alloys are used widely in cast forms for heat-treating, carburizing, and nitriding containers and fixtures, as well as furnace parts. In the wrought

TABLE 4—*Available Specifications*

ALLOY GROUPS AND ALLOYS	ASTM	FEDERAL	U. S. NAVY	MILITARY AERONAUTICAL SPECIFICATIONS	AMS	ASME
Nickel						
Nickel	B 160	—	—	—	—	SB160
	B 161	—	—	—	—	SB161
	B 162	—	—	—	—	SB162
	B 163	—	—	—	—	SB163
Age-hardenable nickel	—	—	—	—	—	—
Nickel-Manganese						
95 Ni—5 Mn	—	—	—	—	—	—
95 Ni—4 Mn—1 Si	—	—	—	—	—	—
Nickel-Copper						
70 Ni—30 Cu	B 127	QQ-N-281	46M7	—	—	SB127
	B 163	—	44T38	—	—	SB163
	B 164	—	—	—	—	SB164
	B 165	—	—	—	—	SB165
Age-hardenable 70 Ni—30 Cu	—	QQ-N-286	46N5	—	—	—
Free-machining 70 Ni—30 Cu	B 164	QQ-N-281	46M7	—	—	SB164
Copper-Nickel						
55 Cu—45 Ni	—	—	17W2	—	—	—
77 Cu—23 Ni	—	—	—	—	—	—
89 Cu—11 Ni	—	—	—	—	—	—
93 Cu—7 Ni	—	—	—	—	—	—
97.5 Cu—2.5 Ni	—	—	—	—	—	—
Nickel-Chromium						
80 Ni—20 Cr	B 82-46	—	17W2	—	5682	—
Nickel-Iron						
70 Ni—30 Fe	—	—	—	—	—	—
50 Ni—50 Fe	—	—	—	—	—	—
42 Ni—58 Fe	—	—	—	—	—	—
36 Ni—64 Fe	—	—	—	—	—	—
Nickel-Chromium-Iron						
77 Ni—15 Cr	B 163	—	—	AN-QQ-N-268	5540	SB163
	B 166	—	—	AN-QQ-N-271	5580	SB166
	B 167	—	49T14	AN-WW-T-831	5665	SB167
	B 168	—	—	AN-WW-T-833	—	—
	—	—	—	AN-N-4	5687	—
Age-hardenable 73 Ni—15 Cr	—	—	—	JAN-W-562	5542, 5667, 5668	—
68 to 60 Ni—18 to 15 Cr	B 83-46	—	17W2	—	—	—
39 to 35 Ni—18 to 15 Cr	—	—	—	—	—	—
12 Ni—24 Cr	—	—	—	—	—	—

TABLE 5—*Commercial Names*[a]

ALLOY GROUPS AND ALLOYS	NAMES
Nickel	
Nickel	Nickel
Age-hardenable nickel	Duranickel
Nickel-Manganese	
95 Ni—5 Mn	D Nickel; Mangrid
95 Ni—4 Mn—1 Si	R-63; Hoskins No. 667
94 Ni—3 Mn—2 Al—1 Si	Alumel
Nickel-Copper	
70 Ni—30 Cu	Monel
Age-hardenable 70 Ni—30 Cu	K Monel
Free-machining 70 Ni—30 Cu	R Monel
Copper-Nickel	
55 Cu—45 Ni	Constantan; Copel; Advance; Cupron; Excelsior
70 Cu—23 Ni	Midohm; No. 180 Alloy
89 Cu—11 Ni	95 Alloy; No. 90 Alloy
93 Cu—7 Ni	Lohm; No. 60 Alloy
97.5 Cu—2.5 Ni	30 Alloy
Nickel-Chromium	
90 Ni—10 Cr	Chromel P
80 Ni—20 Cr	Alray A; Nichrome V; Chromel A; Tophet A
74 Ni—20 Cr	Karma
Nickel-Iron	
70 Ni—30 Fe	Hytemco
50 Ni—50 Fe	52 Alloy
42 Ni—58 Fe	42 Alloy
36 Ni—64 Fe	Invar; Nilvar
Nickel-Silicon	
85 Ni—10 Si—4 Cu	Hastelloy D
Nickel-Molybdenum	
65 Ni—28 Mo	Hastelloy B
Nickel-Molybdenum-Chromium-Tungsten	
55 Ni—17 Mo—16 Cr—4 W	Hastelloy C
Nickel-Chromium-Iron	
77 Ni—15 Cr	Inconel
Age-hardenable 73 Ni—15 Cr	Inconel X
68 to 60 Ni—18 to 15 Cr	Alray C; B&W 700; B&W 701; BTG; Calite N; Chromel C; Empire 60-20; Fahralloy No. 5; Fahralloy No. 6; Amsco F5; Amsco F6; Fahrite; Fernite 1; Firarmor A; Firarmor B; Misco HN; NIC; Nichroloy; Nichrome; Par 8; Premier C; Q Alloy A; Q Alloy B; SSS; Standardalloy HR4; Sweetalloy 21; Thermalloy A; Tophet C; Wehralloy No. 9; Westeeco No. 5
39 to 35 Ni—18 to 15 Cr	Alray D; Amsco F1; B&W 1300; Calite A; Chromax; Chromel D; Chromel 502; Circle L32; Cooper 20; Duraloy; EM 35-15; Fahralloy F1; Fahrite N1; Fernite 2; Midvaloy 17-35; Misco Metal; NA-2; NIC; Pyrasteel 20; SSS; Sivyer 70; Standardalloy HR3; Sweetalloy 20; Thermalloy B; Thermalloy 50; Tisco 120; X-B; X-ite; Zorite; 330 Stainless Steel; 36-N
12 Ni—24 Cr	X-7; 309 Stainless Steel; Almet 25-12; Hoskins No. 670

[a] This list may not be complete. These alloys may also be commercially obtainable under other names.

condition, their high resistivity and resistance to oxidation have led to uses for both electrical and mechanical purposes, similar to the *80 nickel—20 chromium* alloy but for milder applications and at a lower cost.

39 to 35 Nickel—18 to 15 Chromium—These alloys are alloys of the general type known as 330 stainless steel, and have properties similar to those of the higher nickel-content alloys. In cast forms, the alloys are used for many industrial furnace parts and are dependable for continuous operation at advanced temperatures and continuous loading, but are not as resistant to carbon penetration and to oxidation as the alloys with higher nickel contents. In wrought forms, they are useful as a heating element up to surface temperatures as high as 1400 F.

12 Nickel—24 Chromium—This alloy is known generally as 309 stainless steel and is used extensively for heat-resisting applications in sulfur-containing furnace atmospheres. Because of certain limiting factors, it is not recommended for general utility as a heat-resisting alloy in sulfur-free atmospheres.

85 Nickel—10 Silicon—4 Copper—This alloy has high hardness and good resistance to abrasion and is used for handling corrosive liquids containing suspended abrasive matter.

65 Nickel—28 Molybdenum—This is a chromium-free alloy which is used for heat-exchanger units for heating or cooling corrosive media, and for gas turbine applications, bolting, shafting, and similar items subject to high stresses at temperatures up to 1400 F in oxidizing atmospheres and to higher temperatures in reducing atmospheres.

55 Nickel—17 Molybdenum—16 Chromium—4 Tungsten—This heat-resisting alloy is used for combustion cups for diesel engines and for a wide variety of purposes involving resistance to corrosion and thermal shock at temperatures up to 1800 F.

Bearing and Bushing Alloys

SAE General Information

Report of Nonferrous Metals Technical Committee approved February 1947 and last revised by Nonferrous Metals Technical Committee January 1951.

The choice of the material to use for main and connecting-rod bearings depends upon a number of factors among which are fatigue resistance, corrosion resistance, conformability, embeddability, wear resistance, and abrading tendency.

Relative importance of the above factors will depend on each particular application. The resistance to fatigue of bearing materials depends to a great extent upon the design of the bearing, the strength and rigidity of the supporting structure, the thickness of the backing metal (steel or bronze), the thickness of the bearing material, and the physical properties of the bond between the bearing material and the backing. The resistance to corrosion depends upon the chemical composition and characteristics of both lubricant and bearing alloy, and upon temperature and other operating conditions.

The tin- and lead-base babbitts exhibit a minimum tendency to abrade or wear the bearing journal and also are resistant to corrosion from organic acid of the type normal to lubricating oil. Bearings of SAE 15 should not be subjected to the action of break-in oils containing oleic or similar acid. Bearings of any of these alloys show the greatest life when used in thicknesses of 0.005 in. or less.

Bearings of these alloys may be formed by casting in place in cylinder blocks or connecting rods. However, to an increasing extent the alloys are cast on steel and made into inserts with thin coatings of bearing alloys on one or both sides of a steel reinforcement.

Copper-lead bearings are inferior to tin- and lead-base babbitts in nonabrasive properties, but when properly made they have superior resistance to fatigue. Used as insert bearings, they may be made by casting on a formed steel backing or continuous steel strip preferably with provision for rapid cooling or chilling from the molten condition, or they may be made by sintering the powdered metals on a steel strip. Alloying of the copper-lead with a small per cent of silver is desirable for some applications. The general performance of copper-lead bearings when used under extreme service conditions may be improved by plating the bearings with a corrosion-resistant coating of lead-tin or other suitable alloy up to 0.002 in. thickness.

Cadmium alloy bearings may approach the tin- and lead-base babbitts in non-scoring and non-wearing characteristics and the copper-lead bearings in resistance to fatigue. Cadmium bearings are subject to corrosive attack by oils containing fatty oil or acid additives or which develop acids in operation if the oils are used at sufficiently elevated temperatures. Plating cadmium bearings with indium has given considerable protection from corrosion.

Composite bearings consisting of thin lead-babbitt coatings on a matrix of copper and nickel powders sintered to a steel backing show very desirable characteristics as regards resistance to both fatigue and corrosion.

Bearings made of pure silver on a steel backing, plated with lead and indium or lead and tin, have been used for very heavy-duty service where the high cost is warranted. For bearings of this type, see AMS 4815.

Bearings for lighter duty, including split and solid bushings, may be made from a number of alloys depending upon design and operating conditions. Rolled split bushings are made from wrought alloys having suitable bearing and fabricating properties. Comsite bearings and bushings are made by casting or sintering a bearing alloy onto a suitable backing material, usually steel SAE 1010 or 1015. Hardness may be controlled by rolling and annealing practices.

Babbitt Bearing Alloys

SAE Standard

Report of Nonferrous Metals Division approved June 1911 and last revised by Nonferrous Metals Technical Committee January 1950.

	SAE 10		SAE 11		SAE 12[a]		SAE 13		SAE 14		SAE 15	
Similar Specifications	ASTM B 23, Alloy 1 AMS 4800				ASTM B 23, Alloy 2				ASTM B 23, Alloy 7		ASTM B 23, Alloy 15	
Composition,[b] %	Bearing	Ingot	Bearing	Ingot	Bearing	Ingot	Bearing	Ingot	Bearing	Ingot	Bearing	Ingot
Sn, minimum	90.0	90.75	86.0	87.25	88.25	89.0	5.0–7.0	5.5–6.5	9.25–10.75	9.75–10.25	0.9–1.25	1.0–1.25
Sb	4.0–5.0	4.25–4.75	6.0–7.5	6.5–7.0	7.0–8.0	7.25–7.75	9.05–11.0	9.5–10.5	14.0–16.0	14.75–15.25	14.00–15.50	14.75–15.25
Pb	0.50	0.35	0.50	0.35	0.50	0.35	Remainder		Remainder		Remainder	
Cu	4.0–5.0	4.25–4.75	5.0–6.5	5.5–6.0	3.0–4.0	3.0–3.5	0.50	0.25	0.50	0.50	0.50	0.50
Fe	0.08	0.08	0.08	0.08	0.08	0.08	—	—	—	—	—	—
As	0.10	0.10	0.10	0.10	0.10	0.10	0.25	0.20	0.60	0.60	0.80–1.20	0.90–1.10
Bi	0.08	0.08	0.08	0.08	0.08	0.08	—	—	—	—	—	—
Zn	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Al[c]	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Other elements, total	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

[a] Formerly SAE 110.

[b] All values not given as ranges are maximum except as shown otherwise.

In checking bearings to the specifications given, analyses shall be made on samples taken between the bearing surface and a point midway between the bearing surface and the metal backing. Analyses shall regularly be made only for the elements specifically mentioned in the table. If, however, the presence of other elements is suspected or indicated in the course of routine analysis, further analyses shall be made to determine that the total of these other elements is not in excess of the limits specified.

[c] Defined as 0.005% in a 10 gm sample.

Main and Connecting-Rod Bearing Alloys

SAE Standard

Report of Nonferrous Metals Division approved January 1939 and last revised by Nonferrous Metals Technical Committee January 1951.

Silver Bearing Alloys—For information on silver bearings, see SAE General Information on Bearing and Bushing Alloys.

Cadmium Bearing Alloys—All values for compositions of SAE 18 and 180 not given as ranges are maximum except as shown otherwise.

COMPOSITION, %	SAE 18	SAE 180
Cd, minimum	98.4	98.25
Ni	1.0–1.6	0.25
Ag	0.01	0.5–1.0
Cu	0.20	0.4–0.75
Sn	0.02	0.02
Pb	0.05	0.05
Zn	0.15	0.15
Bi	0.02	0.02

Copper-Lead Bearing Alloys—All values for compositions of SAE 48, 480, and 49 not given as ranges are maximum. A corrosion-resistant overlay may be used with alloys SAE 48 and 480, and is recommended for alloy SAE 49. SAE 48 is similar to AMS 4820.

COMPOSITION, %	SAE 48	SAE 480	SAE 49
Cu	67.0–74.0	60.0–70.0	73.0–79.0
Pb	25.0–32.0	30.0–40.0	21.0–27.0
Ag	1.5	1.5	—
Zn	0.1	—	—
P	0.025	—	—
Fe	0.35	0.35	0.35
Sn	0.25	0.50	0.50
Other elements	0.15	0.3	0.45

(Continued on next page.)

Miscellaneous Copper-Base Alloys—SAE 791 and 795 are rolled or wrought and may be indented or graphited or both. SAE 792, 793, and 794 are cast linings or cast and rolled linings on steel back with a maximum 0.25% antimony to prevent rolling difficulties. SAE 797, 798, and 799 are linings of powdered metal sintered to a steel back. All values for compositions of these alloys not given as ranges are maximum except as shown otherwise.

COMPOSITION, %	SAE 791 Rolled or Wrought	SAE 792 Cast Lining / SAE 797 Sintered Lining	SAE 793 Cast Lining / SAE 798 Sintered Lining	SAE 794 Cast Lining / SAE 799 Sintered Lining	SAE 795 Rolled or Wrought
Cu	remainder	77.0 min.	83.0 min	68.5–75.5	88.0–92.0
Sn	3.5–4.5	9.0–11.0	3.5–4.5	3.0–4.0	0.25–0.75
Pb	3.5–4.5	9.0–11.0	7.0–9.0	21.0–25.0	—
Zn	1.5–4.0	0.75	4.0	3.0	remainder
Sb	—	0.5	0.5	0.5	—
Ni	—	0.5	0.5	0.5	—
Fe	0.1	0.35	0.35	0.35	0.1
Other elements	0.2	0.4	0.3	0.4	0.2

Sintered Metal Powder Bearings

SAE General Information

Report of Nonferrous Metals Division approved January 1939 and last revised by Nonferrous Metals Technical Committee February 1947.

[*Sintered metal powder bearings are often used where self-lubrication, low coefficient of friction, accurate dimensions, and simplicity of installation without much machining are definite advantages. Automotive applications include pedal bushings; clutch pilot bearings; clutch throw-out bearings; water-pump, generator, distributor, windshield wiper, steering gear, and transmission thrust washers. General industrial applications include motors, conveyors, farm implements, textile machinery, refrigerators, vacuum cleaners, washing machines, machine tools, and railroad equipment.*]

Sintered metal powder bearings, oil impregnated, are available in the following types and classes:

Type I, Bronze Base—Class A, Copper-Tin; Class B, Copper-Lead-Tin

Type II, Iron Base—Class A, Iron-Carbon; Class B, Iron-Copper

TABLE 1—*Chemical Compositions*

ELEMENTS	TYPE I		TYPE II	
	Class A	Class B	Class A	Class B
Copper	87.5–90.5	82.6–88.5	—	5.0–30.0
Iron, minimum	—	—	95.0	Remainder[b]
Tin	9.5–10.5	9.5–10.5	—	—
Lead	—	2.0–4.0	—	—
Zinc, maximum	—	0.75	—	—
Nickel, maximum	—	0.35	—	—
Antimony, maximum	—	0.25	—	—
Carbon[a]	1.5 max	1.5 max	0.5–2.0	—
Total other elements, maximum	0.5	0.5	3.0	3.0

[a] Commonly graphite. Up to 1½% maximum of another type of solid lubricant may be substituted when authorized by purchaser.
[b] Total iron plus copper shall be 97% minimum.

Chemical Composition—The chemical compositions of these sintered metal powder bearings are given, in %, in Table 1.

Physical Properties—The density requirements of these bearings are given in Table 2.

TABLE 2—*Density Requirements*

TYPE	CLASS	DENSITY, GM PER CU CM	
		Minimum	Maximum
I	A	6.4	6.8
I	B	6.5	6.9
II	A	5.7	6.1
II	B	5.8	6.2

The radial crushing strength shall not be less than the value obtained by applying the following formula:

$$P = \frac{(KLT^2)}{D - T}$$

where

D = outside diameter of bearing, in.
K = strength constant in Table 3 for type specified
L = bearing length, in.
P = radial crushing load, lb
T = wall thickness of bearing, in.

The radial crushing strength shall be determined from the application of a load to the sample by compressing it between two flat surfaces, the direction of the load being normal to the longitudinal axis of the sample. The crushing load is taken at the point when the load drops because of the first crack. This test is

applied to plain cylindrical bearings. Flanged bearings are tested by cutting off the flange and compressing the two sections separately. Both sections shall meet the minimum strength requirements as calculated by the formula given above for radial crushing strength.

TABLE 3—*Strength Constants*

TYPE	CLASS	STRENGTH CONSTANT, *K*
I	A, B	22,500
II	A, B	40,000

The permissible loads on these bearings are given in Table 4 for velocities up to 200 ft per min. For velocities over 200 ft per min, use formula PV = 50,000, where P is the safe load per square inch of projected area, and V is the shaft velocity in feet per minute.

TABLE 4—*Permissible Loads*

VELOCITY, FPM	PERMISSIBLE LOADS, TYPE I, LB PER SQ IN.	PERMISSIBLE LOADS, TYPE II, LB PER SQ IN.
Slow and intermittent	4000	8000
25	2000	3000
50–100	500	700
100–150	325	400
150–200	250	300

Dimensional Tolerances—The commercial dimensional tolerances are given in Table 5.

Bore sizes after installation are kept to desired limits without reaming by allowing for reduction in bore size due to press fit in housing and by using inserting plugs which prevent tight bores and misalignment. Very close limits (±0.0001 in.) can be obtained by subsequent burnishing or machining operations. Machining must be done by methods which will not produce closing of the pores of the metal.

TABLE 5—*Commercial Dimensional Tolerances*

STYLE	DIMENSION	BEARING SIZES, IN.	TOTAL TOLERANCE, IN.
Plain and flange bearings	Inside diameter and outside diameter	*Inside diameter*	
		Up to 1½, inclusive	0.001
		Over 1½ up to 2½, inclusive	0.0015
		Over 2½	0.002
Plain and flange bearings	Length	*Length*	
		Up to 1½, inclusive	0.010
		Over 1½ up to 3, inclusive	0.015
		Over 3	0.020
All bearings	Concentricity	*Inside diameter*	
		Up to 1½, inclusive	0.0015 (0.003[a])
		Over 1½	0.002 (0.004[a])
Thrust bearings	Inside diameter	*Inside diameter*	
		Up to 1¼, inclusive	0.003
		Over 1¼	0.010
Thrust bearings	Outside diameter	*Outside diameter*	
		Up to 1½, inclusive	0.010
		Over 1½	0.020
Thrust bearings	Thickness	All sizes	0.005

[a] Total dial indicator reading.

Copper- and Silver-Base Brazing Alloys

SAE General Information

Report of Iron and Steel and Nonferrous Metals Technical Committees approved January 1947 and last revised January 1949.

Brazing can be defined as a group of metal-joining processes wherein the metals to be joined are heated to temperatures below their melting points, and a nonferrous filler metal having a melting point not lower than 800 F is used.

Capillary brazing defines that type of brazing wherein the parts to be joined are closely fitted and capillary attraction causes the brazing alloy to flow into the joint area.

Capillary-brazing alloys may be classified into two groups: those containing silver (silver brazing alloys—sometimes called silver solders), and those with copper as the predominant material (copper-base brazing alloys).

Ferrous alloys such as cast irons, malleable iron, wrought iron, carbon steels, alloy steels, galvanized iron, and galvanized steel are very successfully brazed with both groups of alloys. The base metals are not melted. With many metals, joints can be formed that are as strong as the parent metal, provided optimum

fits are used. The temperatures required are low as compared with welding, hence minimize structural changes with subsequent hardening which occurs in gray cast iron and malleable iron when higher temperatures are employed.

Copper, brass, and bronze can also be successfully brazed with these alloys. Care should be exercised in selection of brazing alloys for brass and bronzes to keep their melting points below those of the alloys to be joined. Many dissimilar metals may also be readily brazed when the precautions noted above are observed. The brazing of high-nickel alloys with brazing alloys containing phosphorus is not recommended because the phosphorus has an embrittling effect at brazing temperatures. High-nickel alloys and steel parts may crack if brazed while in a state of a high stress.

The silver brazing alloys are usually compositions containing various percentages of silver, copper, and zinc, although in some proprietary alloys cadmium or phosphorus is added in substantial quantities to lower the melting point. Nickel, tin, or manganese may be added to obtain some special property for particular applications, although their use is relatively infrequent. The choice of the particular silver brazing alloy to use can be made from Table 2 and the explanatory notes.

Some of the important characteristics of silver brazing alloys are high shock and vibration resistance at ordinary temperatures, melting points in the range of 1200–1600 F, free-flowing capillary action, and excellent resistance to corrosion. Since the first cost of silver brazing alloys is higher than that of other metal-joining materials, their application must be predicated on needed characteristics which only they possess, or on processing economies which may result. If in a proposed application a joint resistant to severe shock, vibration, and high strength is required, the use of soft solder is not recommended. Either copper or silver brazing alloys should be used. If temperatures over 1600 F cannot be tolerated, the choice is further narrowed to silver brazing alloys or phosphorus-copper alloys of near eutectic composition. The fit of the joint also influences alloy selection. If the joint has a close fit (0.001–0.003 in. clearance) requiring free-flowing capillary action, silver alloys are recommended. Actual press fits, however, are frequently brazed using hydrogen brazing with pure copper rather than alloys. Press fits should be avoided on other than copper-hydrogen brazing.

Brazing alloys are usually furnished as rod or wire for hand feeding. For applications of high production when the alloy is preplaced, other forms such as specially formed sheets, rings, or strips may be used. Under special conditions, powdered or granular forms may be employed.

To produce a satisfactory brazed joint certain precautions must be taken. The parts to be brazed should be very thoroughly cleaned so that all scale, oxides, grease, oil, dirt, or other foreign materials are removed. A flux should be used that is fluid and active at the flow point of the brazing alloy. The flux should be applied evenly with care being taken to see that no bare spots remain. Best results will be obtained if the alloy as well as the joint is protected with flux. When inserts are used and the brazing alloy and the surfaces of the joint are not directly exposed to the flame or to oxidation, use only a very thin coating of flux.

Care should be taken to see that all joints to be brazed fit properly. It is advisable to use inserts of the brazing alloy when ever possible. When thin-sheet inserts are used, a slight pressure should be applied. Suitable jigs and supports should be provided to hold the parts firmly in position to maintain proper clearance and alignment until the brazing alloy has set. When heating with a torch, use a tip sufficiently large to give the necessary heat with a soft neutral or slightly reducing flame. The joint should be heated evenly; where heavy and light sections are joined, be sure that the heavy section is brought to the proper temperature. As a general rule the best results are obtained when the joint is heated rapidly and when kept at the brazing temperature for a minimum time required for proper flowing of the alloy. Whenever possible, avoid strong drafts and varying light conditions in the vicinity of the brazing operation.

Do not use any more heat than is necessary and remember that one of the principal advantages of silver brazing alloys is the low temperature at which they can be used. Carefully designed silver-brazed joints are frequently capable of developing shear strengths as great as 50,000 psi. Generally it is not recommended that silver-brazed joints be used in service where the operating temperatures exceed 400 F. In some instances where fatigue and strength requirements are low, this temperature may be exceeded. This is best determined by tests.

When copper-brazed joints are made prior to heat-treatment of the parts in the assembly, a brazing alloy should be chosen whose melting point is at least 350 F higher than the heat-treating temperature.

Table 1 gives the composition and use of some of the copper-base brazing alloys that are commonly used. Table 2 gives the

TABLE 1—*Composition and Properties of Copper-Base Brazing Alloys*

CLASS OF ALLOY	Cu	Sn	Zn	OTHER ELEMENTS	FLOW POINT, F
A—Copper	99.9 min	—	—	—	1980
B—Phosphor-copper	Remainder	—	—	4.5–5.5 P	1525
C—Phosphor-bronze	Remainder	9.0–11.0	0.2 max	0.03–0.25 P	1830
D—Copper-silicon	94.8 min	0.75 max	1.5 max	2.75–3.5 Si 1.50 Mn, max 1.60 Fe, max 0.05 Pb, max	1880
E—Low-fuming brass	Remainder	0.75–1.1	38–42	0.1 Mn, max 0.7–1.2 Fe 0.04–0.14 Si	1650
F—Naval brass	59–62	0.4–1.5	Remainder	—	1650
G—Brass brazing alloy	61–67	—	Remainder	—	1700
H—Copper-silicon	99.7 min	—	—	0.3 Si	1980

TABLE 2—*Composition and Properties of Silver Brazing Alloys*

CLASS[a]	Ag	Cu	Zn	Cd	P	MELTING POINT, F	FLOW POINT, F	COLOR	ELECTRICAL CONDUCTIVITY, Cu = 100
A	9.0–11.0	51.0–53.0	36.0–40.0	—	—	1510	1600	yellow	20.5
B	19.0–21.0	44.0–46.0	33.0–37.0	—	—	1430	1500	yellow	24.4
C	29.0–31.0	37.0–39.0	30.0–34.0	—	—	1370	1410	yellow-white	—
D	39.0–41.0	35.0–37.0	22.0–26.0	—	—	1330	1445	nearly white	—
E	44.0–46.0	29.0–31.0	23.0–27.0	—	—	1250	1370	nearly white	—
F	49.0–51.0	33.0–35.0	14.0–18.0	—	—	1280	1425	nearly white	24.4
G	59.0–61.0	24.0–26.0	13.0–17.0	—	—	1260	1325	white	—
H	14.0–16.0	79.0–81.0	—	—	4.75–5.25	1190	1300	gray-white	14.0
I	49.0–51.0	14.5–16.5	14.5–18.5	17.0–19.0	—	1160	1175	yellow-white	23.9

[a] Other alloys of different chemical composition are available that have the same physical properties and similar melting- and flow-point temperatures.

composition and use of some of the silver brazing alloys that are commonly used.

Applications of Copper Brazing Alloys—*Class A*—Used on ferrous, nickel, and monel parts. Can be furnace brazed in a non-oxidizing atmosphere without flux or brazed in a suitable high-temperature salt bath. Can also be used with an oxyacetylene torch. Wets low carbon steel easily. Excellent for corrosion resistance, good strength, and resistance to vibration and impact.

Class B—Used for sweat brazing overlapping surfaces of copper or copper alloys. Not recommended for steel, cast iron, or high-nickel alloys. Material is self fluxing on copper.

Classes C and D—Applied by carbon arc or metal arc as a general rule. Can also be used with a torch. Used for building up a wear-resistant surface and joining copper to steel. Can also be used on copper, brass, bronze, stainless steel, galvanized iron and steel.

Class E—Used in open vee, fillet, or sweat-brazed connections yielding high strength joints. Works satisfactorily on copper, nickel, monel, cast irons and steels, and dissimilar metals. Caution needs to be taken where these metals are chosen for the specific corrosion resistance in certain envornments. This alloy also gives good wear resistance.

Class F—Excellent rod for brazing on brasses, copper, nickel alloys, cast iron, malleable iron, and steel. It is tough, durable, strong, and easy to apply.

Class G—Inexpensive, moderate-strength connections used on copper alloys, nickel alloys, cast iron, and steel. Not recommended for open vee or fillet connections.

Applications of Silver Brazing Alloys—*Classes A, B, and C*—This group contains the low-silver brazing alloys which can b used on iron, steel, and nonferrous alloys that are not damage by the temperature of application of the particular alloy used The choice of grade depends on the cost of the alloy, evaluate against the deposition temperature, color, and subsequen heating. They have relatively high strength, malleability, duc tility, and a low initial cost directly proportional to their silve content.

Classes D, E, and F—These alloys are also applied to iron steel, and nonferrous alloys. They are higher grade materials tha classes A, B, and C with respect to strength and corrosion re sistance, and their color is nearly white.

Class E—This alloy has the lowest flow point of this group an can be used on monel metal providing care is exercised to avoi overheating.

Class G—This alloy is used on small parts and monel meta where its low flow point (1325 F) is advantageous. No other allo with a lower silver content is completely white.

Class H—This alloy is recommended for use on copper an copper-base alloys. It has a low melting point and is self fluxing It is not recommended for use on monel metal, nickel, nicke alloys, iron, or steel.

Class I—This alloy is one of a series of proprietary low melting point (1175 F) silver brazing alloys. The analysis shown is on which is most extensively used. It has good physical properties and can be used on steel, stainless steel, iron, copper-base alloys nickel, and nickel alloys.

Solders

SAE Standard

Report of Nonferrous Metals Division approved June 1911 and last revised by Nonferrous Metals Technical Committee February 1947.

The choice of the type and grade of solder for any specified purpose depends on the material in connection with which it is to be used and the method of applying. For galvanized iron and zinc, only Class A should be used. Class A solder should be furnished under this specification unless otherwise specified.

It is recommended that the grade of solder metal be selected that contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

Class B solders are wiping type.

Maximum Impurities, %

Bismuth	0.25	Zinc	0.005
Copper	0.08	Aluminum	0.005
Iron	0.02	Other elements, total	0.08

In dipping solders, 0.5% maximum copper is permissible because of pick-up in bath.

Compositions, temperatures, and similar specifications of these SAE solders are shown in Table 1.

TABLE 1—*Compositions, Temperatures, and Similar Specifications*

SAE No.	TIN	LEAD	ANTIMONY	TEMPERATURES				SIMILAR SPECIFICATIONS ASTM B 32
				Solidus		Liquidus		
				F	C	F	C	Grade
1A	45.0, − 1.0	Remainder	0.4 max	361	183	414	212	Alloy 45B
1B	43.0, + 0.5	Remainder	1.5–2.00	361	183	405	208	
2A	40.0, − 1.0	Remainder	0.4 max	361	183	460	238	Alloy 40B
2B	38.0, + 0.5	Remainder	1.5–2.00	361	183	450	232	
3A	30.0, − 1.0	Remainder	0.4 max	361	183	494	257	Alloy 30B
3B	28.0, + 0.5	Remainder	1.5–2.00	361	183	484	251	
4A	25.0, − 1.0	Remainder	0.4 max	361	183	511	266	Alloy 25B
4B	25.0, − 1.0	Remainder	1.25–1.75	361	183	502	261	
5A	20.0, − 1.0	Remainder	0.4 max	361	183	525	274	Alloy 20B
5B	20.0, − 1.0	Remainder	1.25–1.75	361	183	518	270	
6A	15.0, − 1.0	Remainder	0.4 max	361	183	543	284	Alloy 15B
6B	15.0, − 1.0	Remainder	As specified[a]	361	183	532–541	278–283	

[a] Maximum, 2.75%.

Wire Cloth

SAE Standard

Report of Parts and Fittings Division approved July 1924.

Dimensions of wire cloth are given in Table 1.

TABLE 1—*Wire-Cloth Dimensions*

MESH	DIAMETER OF WIRE, IN.	SIZE OF OPENING, IN.	PROPORTION OF OPENINGS TO TOTAL AREA, %[a]	MESH	DIAMETER OF WIRE, IN.	SIZE OF OPENING, IN.	PROPORTION OF OPENINGS TO TOTAL AREA, %[a]
8	0.028	0.097	60	45	0.0095	0.0130	34
10	0.025	0.075	56	50	0.009	0.0110	30
12	0.023	0.060	52	60	0.008	0.0090	29
14	0.020	0.051	51	70	0.007	0.0073	26
16	0.018	0.044	51	80	0.006	0.0068	29
20	0.016	0.034	46	90	0.005	0.0059	28
24	0.015	0.027	42	100	0.0045	0.0055	30
30	0.013	0.021	40	120	0.004	0.0043	26
35	0.011	0.018	40	150	0.003	0.0037	31
40	0.010	0.015	36	200	0.0021	0.0029	33

[a] This column is given for information only. The areas are based on the nominal wire sizes.

Mesh denotes the number of openings per inch.

The weave shall be what is known as 'plain,' except that in meshes 80 and finer, 'twilled' weave may be used.

Double crimped wire shall be used and woven so as to give square openings.

The accuracy of spacing wires shall be such as to give openings within 10%, plus or minus, of the openings specified.

The variation in the diameter of the wire shall not exceed the following plus and minus tolerances in inches:

Up to and including 16 mesh	0.003
From 20 to 50 mesh	0.002
From 60 to 100 mesh	0.0015
Above 100 mesh	0.001

The material shall be specified by the purchaser, taking account of the fact that manufacturers of wire cloth stock these meshes in steel and brass up to about 80 mesh; above this, it is common practice to supply phosphor bronze and monel metal.

Electroplating Practice

SAE General Information

Report of Nonferrous Metals Division approved January 1930 and last revised by Nonferrous Metals Technical Committee January 1950.

Electroplating is extensively used in the automotive industries and is continuing to enlarge its useful functions. Various plated metals and combinations of these are being used for different purposes, some of which are as follows:

1. Decoration or protection against corrosion or both: copper, nickel, and chromium singly or in combination
2. Protection against corrosion: cadmium or zinc
3. Protection against wear: chromium alone or in combination with copper or nickel or both
4. Build up of undersize parts: chromium, nickel, or iron
5. Adhesion of rubber to steel: brass
6. Protection against carburizing and nitriding: copper, tin, nickel, bronze
7. Protection against friction: tin, cadmium, copper, lead
8. Plating for brazing: copper
9. Electroforming: copper, nickel, iron
10. Minor uses such as identification

Decoration or Protection Against Corrosion or Both—Numerous automotive parts such as bumpers, body hardware, grilles, hub caps, and bezels made of various metals such as steel, brass, zinc-base die-cast alloy, and stainless steel are commonly chromium plated for decorative purposes and for protection against corrosion. The plating usually is made up of a very thin layer of chrome applied over a much heavier undercoat of nickel or of copper and nickel. The undercoats furnish most of the protection from corrosion, while the chromium plating prevents tarnishing of the nickel plate.

Copper Plating—While electrodeposited copper (sometimes oxidized or otherwise colored) protected from tarnish by a clear organic film is occasionally used in automotive work as decorative finish, it is most commonly used under nickel and chromium on steel parts and on parts die cast of a zinc-base alloy. On either base metal, electrodeposited copper may serve several purposes. On steel it may be employed as a thin, "strike" deposit to complete the cleaning preparation for nickel plating. In greater thicknesses it may be buffed to produce a high luster and to cover or minimize wheel marks or base-metal defects. On zinc-base die castings it is used to facilitate subsequent deposition of nickel and for protection against corrosion. A "strike" deposit of copper is sometimes used to complete the cleaning preparation of brass for nickel plating.

In all cases, the initial deposit of copper is obtained from a cyanide bath containing copper cyanide, sodium cyanide, sodium carbonate, and frequently sodium hydroxide and Rochelle salts. Where deposits thicker than 0.0002 to 0.0003 in. are desired, it is customary to transfer parts after preliminary plating in a cyanide bath to a bath which permits formation of superior deposits or deposits at higher speed, such as an acid-copper bath (containing copper sulfate and sulfuric acid) or one of the proprietary baths now available.

The proprietary baths are of several types. One is a highly concentrated cyanide bath operated at a high temperature to which organic addition agents are added. For it, high efficiency and improved luster of deposit is claimed. Others are standard acid-copper baths modified by organic additions to improve luster and buffability. Another is an ammoniacal copper sulfate solution modified by the addition of an organic material. Another is an alkaline pyrophosphate solution. The latter two baths permit deposition of bright copper. In all cases agitation is recommended.

Nickel Plating—Nickel plating is applied over the various base metals or over the various base metals after copper plating. It affords protection against corrosion in proportion to its thickness. It may be buffed to cover or minimize wheel marks and base-metal defects. The standard nickel-plating bath is the Watts bath containing nickel sulfate, nickel chloride, and boric acid. This bath produces a matte deposit which must be buffed for luster. In recent years it has been modified by the addition of acid (low pH) and considerable increase in amount of nickel chloride used to permit more rapid deposition of a more easily buffed deposit and to promote anode corrosion.

In recent years semi-bright and bright nickel plating have come into general use in the industry. Their principal advantage is lower costs in the case of the semi-bright deposits due to a reduction in the amount of buffing required and to its elimination in the case of bright deposits. Some of these solutions also exhibit a marked tendency to obliterate surface defects such as scratches and grinding lines in the base metal and thus minimize the amount of polishing required prior to plating. Better quality at times may also be attained as the hazard of buffing through at sharp edges or corners is minimized.

There are several types of bright nickel solutions in general use. One type depends mainly on cobalt as the addition agent which causes brightness. There is another type which uses organic addition agent plus zinc. There are still others with various materials added for the brightening effect. These baths are operated at the usual operating temperatures of other nickel baths. Also, current densities are of the same order in most cases as the dull nickel baths. Agitation of some sort is generally required.

Bright nickel solutions are generally used in rubber-lined tanks. In past years there has been an expanded use of continuous filtration, external heating, and the use of activated carbon to remove impurities.

Chromium Plating—Chromium plating is used in thin deposits over nickel plate because of its high resistance to tarnishing. The only exception to this is in the case of stainless steel which is plated directly with chromium to impart a blue-white color to match that of other parts which are chromium plated and to improve its tarnish resistance. Chromium plating is performed in a bath containing a high percentage of chromic acid, a much smaller percentage of sulfuric acid, or less frequently hydrofluoric fluorsilicic acid. Insoluble anodes, usually lead, are used. The bath composition is maintained by additions of chromic acid.

Plating Specifications—Automotive parts are plated to specifications which call for definite thicknesses of the protecting metals.

Tentative ASTM A 166, Electrodeposited Coatings of Nickel and Chromium on Steel prepared jointly by the American Society

for Testing Materials and the American Electroplaters' Society, specifies the following thicknesses in inches:

	DS	FS	KS	QS
Copper plus nickel, min	0.0020[a]	0.00125	0.00075	0.0004
Final nickel, min	0.0010	0.0006	0.0004	0.0002
Chromium (if required), min	0.00001	0.00001	0.00001	0.00001

[a] When copper is used in excess of a thickness of 0.0001 in., its minimum thickness shall be 0.00075 in.

Zinc-Alloy Die Castings—In plating zinc-alloy die castings, it is essential to deposit a substantial thickness of copper prior to depositing a sufficient thickness of nickel to meet specifications for total thickness of deposits. Tentative ASTM specifications for Electrodeposited Coatings of Nickel and Chromium on Zinc and Zinc-Base Alloys (ASTM B 142) prescribe the following thicknesses in inches:

	FZ	KZ	QZ
Copper plus nickel, min	0.00125	0.00075	0.0005[a]
Copper, min	0.0004	0.0003	0.0002
Final nickel, min	0.0005	0.0003	0.0003

[a] Total of 0.0003 in. minimum if alternative of nickel only is used.

Copper and Copper-Base Alloy Parts—Tentative ASTM B 141, Electrodeposited Coatings of Nickel and Chromium on Copper and Copper-Base Alloys prescribes the following thicknesses in inches:

	FC	KC	QC
Nickel, min	0.0005	0.0003	0.0001
Chromium,[a] min	0.00001	0.00001	0.00001

[a] Chromium coatings 0.000025 in. or more in thickness are likely to cause crackings of nickel deposits. The minimum thickness of chromium should be obtained with as low a maximum thickness as is practicable.

The initial letters D, F, K, and Q were adopted as arbitrary designations of grades of plating. Of the second letters, S refers to steel as base metal, B to brass, C to copper, and Z to zinc.

The above specifications are cited as representing good commercial practice.

Protection Against Corrosion—Some parts are partially or totally concealed because of their position but require protection against rust or corrosion, as bolts, nuts, washers, and chassis parts. On these parts a metallic protection is frequently preferred to paint or enamel to avoid build up on threaded parts or because electrical conductivity must be maintained. For this purpose zinc or cadmium is generally used.

Tentative ASTM A 164, Electrodeposited Coatings of Zinc on Steel prescribes the following thicknesses in inches:

GS, 0.001, min; LS, 0.0005, min; RS, 0.00015, min

Tentative ASTM A 165, Electrodeposited Coatings of Cadmium on Steel, prescribes the following thicknesses in inches:

NS, 0.0005, min; OS, 0.0003, min; TS, 0.00015, min

Zinc is commonly plated from a cyanide bath, though acid baths are also used. Cadmium is plated from cyanide baths.

Cadmium plate is sometimes preferred on the basis of appearance. Under various conditions one or the other of these metals may be preferred, inasmuch as the relative resistance to corrosion varies with the type of corrosive medium. One of the difficulties experienced with zinc deposits has been the tendency for bulky white corrosion products to form when zinc-coated parts are brought in contact with stagnant water or exposed to a highly humid atmosphere. This tendency may be minimized by treating the parts after plating with inhibiting solutions, usually solutions of chromates.

Proprietary solutions for the plating of bright zinc and for the plating of bright cadmium are available.

Steel parts high in carbon or hardened by heat-treatment or cold work may absorb hydrogen and become embrittled in pickling or plating operations. Such parts should be heated to 300 to 400 F for a sufficient period of time to remove this embrittlement.

Care must be exercised in assembly of zinc- or cadmium-plated parts by spot welding. Heavy zinc deposits may cause cracking. Adequate ventilation should be provided when cadmium-plated parts are welded.

Protection Against Wear—Production tools such as plug gages, burnishing tools, and drawing dies are heavily chromium plated to reduce wear. The chromium in this case is applied directly to the steel parts in a bath similar to that used for plating decorative parts. Usually the current density and temperature are increased to get greater speed. Great care is necessary in cleaning, and sometimes etching the surface of the parts before plating is employed to get good adhesion of the plate. Plates varying from 0.0005 to 0.020 in. are being used.

Much lighter deposits have been used effectively on cutting tools. Ordinary decorative chrome plate has been used to control wear in light-duty hydraulic cylinders used for door-closing and top-handling devices.

Engine cylinders and piston rings may be plated with "porous" chromium. The process serves to reduce cylinder wear, ring wear, and ring-groove wear. After plating, by a current-reversal process, the chromium deposit is made "porous"; actually a network of oil-retentive cracks is developed. Ordinary dense chromium is not wetted by oil.

Build Up of Undersize Parts—This is a salvage operation and is generally done with chromium plate. However, the use of nickel or nickel plus chromium is developing, and iron is also used.

Adhesion of Rubber to Steel—Steel parts to which rubber must adhere are often brass plated, which permits a good bond. One of the principal requirements in this operation is a uniform ratio of copper to zinc in the alloy deposited. In order to secure uniformity it is essential to control closely the solution composition, pH, and operating conditions. A cyanide bath containing copper and zinc cyanides in a 2:1 ratio is commonly used.

Protection Against Carburizing and Nitriding—It is sometimes desirable to protect certain areas of carburized parts against carburization. For this purpose a copper deposit of approximately 0.001 in. is often used as a stop off. This may be plated from a cyanide bath, or acid copper over a thin cyanide-copper coating may be used, or one of the proprietary high-speed coppers.

Electrolytic deposits of tin and also nickel and tin bronze are

similarly used as a stop off in nitriding. If too heavy a coating of tin is applied, it will melt and flow and produce defective work. Tin bronze and nickel are free from this defect.

Protection Against Friction—Tin has been used considerably in plating cast-iron pistons in internal-combustion engines. The soft metal flows under pressure and minimizes the danger of scoring of cylinder walls during the break-in period. Cadmium has been used similarly on steel pistons and iron piston rings, and tin by chemical deposition on aluminum pistons. Gears are frequently plated with copper for protection during initial runs.

Plating for Brazing—Copper plate on steel has been employed as a means of assembly by being used as brazing material in hydrogen-brazing operations. Rolled tubing for gasoline and oil lines has been fabricated in this way. Only very closely fitted parts can be assembled in this way.

Electroforming—Patterns are being made of electrodeposited copper, iron, and other metals, and molds for rubber and plastics are being made by this process. Although the art of electroforming has been known for a long time and used in many industries, it has only been in comparatively recent years that its more or less extensive use in the automotive industry has taken place.

Minor Uses Such as Identification—Parts are sometimes identified or uses indicated by means of very thin platings. Plating has also been used in magnetic-particle inspection to provide a background on which the magnetic indications are more readily discerned.

A cross index of SAE designations for materials and parts appears after the last standard in this book.

Classifications and Physical Requirements for Rubber Compounds (SAE R 10)

SAE Standard

Report of Passenger Car Division approved January 1943 and last revised by Nonmetallic Materials Technical Committee January 1951. This SAE Standard conforms with ASTM D 735—50, Tentative Specifications for Rubber and Synthetic Rubber Compounds for Automotive and Aeronautical Applications.

[*The SAE-ASTM Technical Committee on Automotive Rubber formulated this Standard after comprehensive study of other rubber specifications.*

After the standard was approved, the U. S. Government imposed restrictions on the use of natural rubber, and shortages of ingredients for compounds covered by this standard developed. For these reasons, rubber-products manufacturers may not be able to meet the physical requirements specified.]

1. Scope

(a) These specifications cover vulcanized compounds of natural rubber, reclaimed rubber, synthetic rubber, or rubber-like materials, alone or in combination, which are intended for use in manufacturing products for automotive and aeronautical applications. Compounds for tires, inner tubes, sponge rubber, hard rubber, belts, hose, and mats are not included.

(b) The compounds listed in Tables 1–4 are of two types, grouped in four classifications, based primarily on physical properties as defined in Section 6. Although the individual compounds provide a wide variety and range of physical properties, it should be understood that these specifications are general and are intended to furnish a basis for engineers to select a material suitable for applications not covered by detailed product specifications. Care should be taken to choose those grades having only the properties required for the intended service.

Since it is recognized that basic test requirements used mainly to classify compounds do not sufficiently describe some compositions, provision is made for added test requirements which are indicated by suitable suffixes to the grade numbers. When the compounds may be used for purposes where the requirements are too specific to be prescribed in general specifications, it is advisable for the purchaser to consult the manufacturer to secure adjustment of the properties to suit the actual operations to which the material is to be subjected.

(c) In case of conflict between the provisions of these general specifications and those of detailed specifications for a particular product, the latter shall take precedence.

Note—These automotive classified compounds will serve many of the needs of other industries, even as SAE numbered steels are used. It must be remembered however that the classifications are subject to revision when required by automotive needs, and there is no assurance that the changes will be acceptable to all other users.

2. Types of Compounds—These specifications cover two types of compounds designated by the prefix letters R and S as follows:

Type R—Compounds made from natural rubber, reclaimed rubber, synthetic rubber, or rubber-like materials, alone or in combination, for services where specific resistance to the action of petroleum-base fluids is not required.

Type S—Compounds made from synthetic rubber or rubber-like materials for services where specific resistance to the action of petroleum-base fluids is required.

3. Classes and Grades of Compounds

(a) *Classes*—Type R compounds are listed in one class only and Type S compounds are divided into three classes designated by the letters A, B, and C added to the "S" prefix as follows:

Class SA—compounds made from synthetic rubber or rubber-like materials having very low volume swell in low aniline point oils (ASTM D 471—46T).

Class SB—compounds made from synthetic rubber or rubber-like materials having low volume swell in low aniline point oils (ASTM D 471—46T).

Class SC—compounds made from synthetic rubber or rubber-like materials having medium volume swell in low aniline point oils (ASTM D 471—46T).

(b) *Grades*—Each class of compound has a number of different grades[1], each having different physical properties. The grades shall be designated by numbers following the prefix letters and when necessary, by suffix letters after the grade number as follows:

Grade numbers shall consist of three digits, the first indicating the durometer hardness range, for example, 3 for 30 ± 5, 4 for 40 ± 5. The next two digits indicate the minimum tensile strength, for example, 05 for 500 psi, 15 for 1500 psi.

Suffix letters may be added singly or in combination after any grade number to indicate additional requirements beyond those specified in the tables as basic requirements for that particular grade. The significance of the approved suffix letters is as follows:

Suffix Letter

(A).....Suffix A formerly denoting oven-aging requirement is discontinued. Oven aging is a basic requirement in all tables.

B.....Compression-set test required with values as specified in Tables 1, 3, and 4.[2]

C.....Weather-resistance test required.[3]

D.....Load-deflection test required with values as specified in Table 1.

E-1.....Oil-immersion test required with values as specified in Tables 2, 3, and 4. Physical change when immersed in ASTM No. 1 oil.

E-3.....Oil-immersion test required with values as specified in Tables 2, 3, and 4. Physical change when immersed in ASTM No. 3 oil.

F.....Low-temperature test at −40 F required.[3]

FF.....Low-temperature test at −70 F required.[3]

G.....Tear test required.[3]

H.....Flexing test required.[3]

J.....Abrasion test required.[3]

K.....Adhesion test required.[3]

L.....Moisture absorption test required.[3]

M.....Inflammability test required.[3]

N.....Repeated impact test required.[3]

P.....Staining test required.

R.....Resilience test required with values as specified in Table 1.

Z.....Special test required.[3] (Any special characteristics or

[1] It is understood that intermediate grades used prior to the revision of this Standard will continue in use for an extended period.

[2] Note that the letter B now designates the low compression-set values. In previous issues of this Standard, B has indicated the normal-set column which is now basic. The letter B should now be used only where the special low-set values are required.

Example: Grade SB 625 F designates a synthetic compound with good oil resistance having a durometer hardness of 60 ± 5, and an original minimum tensile strength of 2500 psi, and which passes the low-temperature test at −40 F and conforms to the other basic requirements prescribed in Table 2.

[3] Test to be arranged between the manufacturer and the purchaser.

TABLE 1—*Physical Requirements of Type R Compounds, Non Oil Resistant*[a]

GRADE NO.[b]	BASIC REQUIREMENTS							REQUIREMENTS ADDED BY SUFFIX LETTER[c]		
				Heat aged 70 hr at 158 F				Suffixes		
								D	B	R
	Durometer hardness number	Minimum tensile strength, psi	Minimum ultimate elongation, %	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Maximum change in durometer hardness	22 hr at 158 F, maximum compression set, %	20% load deflection, psi	22 hr at 158 F, maximum compression set, %	Minimum resilience under compressive strain, %
R310	30 ± 5	1000	400	−25	−35	+10	50	—	25	—
315	30 ± 5	1500	500	−25	−25	+10	50	70 ± 10	25	—
320	30 ± 5	2000	600	−25	−25	+10	50	70 ± 10	25	—
325	30 ± 5	2500	600	−25	−25	+10	50	70 ± 10	35	—
*R410	40 ± 5	1000	400	−25	−35	+10	50	—	25	—
*415	40 ± 5	1500	500	−25	−25	+7	50	100 ± 15	25	70
*420	40 ± 5	2000	500	−25	−25	+7	50	100 ± 15	25	75
425	40 ± 5	2500	500	−25	−25	+7	50	100 ± 15	25	80
430	40 ± 5	3000	600	−25	−25	+7	50	100 ± 15	35	80
*R505	50 ± 5	500	300	−25	−35	+10	50	—	—	—
*510	50 ± 5	1000	400	−25	−35	+10	50	—	25	—
*515	50 ± 5	1500	400	−25	−25	+7	50	140 ± 20	25	65
*520	50 ± 5	2000	500	−25	−25	+7	50	140 ± 20	25	65
*525	50 ± 5	2500	500	−25	−25	+7	50	140 ± 20	25	75
530	50 ± 5	3000	600	−25	−25	+7	50	140 ± 20	35	75
535	50 ± 5	3500	600	−25	−25	+7	50	140 ± 20	35	75
R605	60 ± 5	500	300	−25	−35	+10	50	—	—	—
*610	60 ± 5	1000	300	−25	−35	+10	50	—	25	—
*615	60 ± 5	1500	350	−25	−25	+7	50	195 ± 30	25	60
620	60 ± 5	2000	400	−25	−25	+7	50	195 ± 30	25	60
*625	60 ± 5	2500	450	−25	−25	+7	50	195 ± 30	25	70
630	60 ± 5	3000	500	−25	−25	+7	50	195 ± 30	35	70
635	60 ± 5	3500	550	−25	−25	+7	50	195 ± 30	35	70
*R705	70 ± 5	500	150	−25	−35	+10	50	—	—	—
710	70 ± 5	1000	200	−25	−35	+10	50	—	25	—
*715	70 ± 5	1500	250	−25	−25	+7	50	300 ± 70	25	50
*720	70 ± 5	2000	300	−25	−25	+7	50	300 ± 70	25	50
725	70 ± 5	2500	300	−25	−25	+7	50	300 ± 70	25	60
730	70 ± 5	3000	400	−25	−25	+7	50	300 ± 70	35	60
*R805	80 ± 5	500	100	−25	−35	+10	50	—	—	—
*810	80 ± 5	1000	150	−25	−35	+10	50	—	—	—
815	80 ± 5	1500	200	−25	−25	+7	50	475 ± 100	—	—
*820	80 ± 5	2000	250	−25	−25	+7	50	475 ± 100	—	—
825	80 ± 5	2500	300	−25	−25	+7	50	475 ± 100	—	—
*R905	90 ± 5	500	75	−25	−35	+10	50	—	—	—
910	90 ± 5	1000	100	−25	−35	+10	50	—	—	—
915	90 ± 5	1500	125	−25	−25	+7	50	—	—	—

[a] This table represents a combination of the RN and RS tables in ASTM D 735—43T and in previous issues of this Standard. See Section 7 for methods of testing.
[b] The compounds marked with an asterisk are those which are most commonly used. It is suggested that these compounds be specified when possible.
[c] See Section 3.

functional requirements other than those prescribed in these suffixes, which may be desired for specific applications, for example, resistance to ozone or special fluids, shall be specified under suffix Z.)

4. **Composition and Manufacture**—Compounds furnished under these specifications shall be manufactured from natural rubber, reclaimed rubber, synthetic rubber, or rubber-like materials together with added compounding ingredients of such nature and quantity as not to prevent compliance with the specified requirements. All materials and workmanship shall be in accordance with good commercial practice, and the resulting

TABLE 2—*Physical Requirements of Synthetic-Rubber Compounds, Type S, Class SA, Oil Resistant*[a]

GRADE NO.	BASIC REQUIREMENTS									REQUIREMENTS ADDED BY SUFFIX[b]					
										Suffix E-3			Suffix E-1		
										70 hr at 212 F, ASTM No. 3 oil			70 hr at 212 F, ASTM No. 1 oil		
	Durometer hardness number	Minimum tensile strength, psi	Minimum ultimate elongation, %	Oil aged 70 hr at 212 F		Heat aged 70 hr at 212 F			22 hr at 158 F, maximum compression set, %	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Change in durometer hardness (limits)	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Change in durometer hardness (limits)
				ASTM No. 3 oil	ASTM No. 1 oil	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Maximum change in durometer hardness							
				Volume change, % (limits)	Volume change, % (limits)										
SA405	40 ± 5	500	400	0 +10	−3 +5	−15	−40	+15	65	−20	−50	−5 +10	−20	−50	−5 +10
SA505	50 ± 5	500	400	0 +10	−3 +5	−15	−40	+15	60	−20	−50	−5 +10	−20	−50	−5 +10
SA607	60 ± 5	700	300	—	−3 +5	−15	−40	+10	50	−20	−50	−5 +10	−30	−50	−5 +10
SA710	70 ± 5	1000	250	0 +10	−3 +5	−15	−40	+10	50	−30	−50	−5 +10	−30	−50	−5 +10
SA810	80 ± 5	1000	150	0 +10	−3 +5	−15	−40	+10	50	−30	−50	−5 +10	−30	−50	−5 +10
SA910	90 ± 5	1000	100	0 +10	−3 +5	−15	−40	+10	50	−30	−50	−5 +10	−30	−50	−5 +10

[a] See Section 7 for methods of testing.
[b] See Section 3.

stock shall be free from porous areas, weak sections, bubbles, foreign matter, or other defects affecting serviceability.

5. **Color**—Unless otherwise specified, these compounds shall be black and free from objectionable bloom.

6. **Physical Requirements**

(a) The values for the physical requirements prescribed in these specifications, together with any additional requirements indicated by suffix letters in the grade designations as described in Section 3, define the properties of the compounds after vulcanization in molds in the form of standard laboratory test slabs or blocks prepared in accordance with the standard methods of sample preparation for physical testing of rubber products (ASTM D 15).

(b) Test results from finished products may not duplicate the values obtained from standard test specimens. When differences due to the method of processing or to the difficulty in obtaining suitable test specimens from the finished part arise, user and producer may agree on acceptable deviations. This can be done by comparing results of standard test specimens and those obtained on actual parts.

7. **Test Methods**—The properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials except as modified in accordance with certain provisions stated herein. All exposure periods and temperatures prescribed in the tables shall be given precedence over those specified in the ASTM methods.

(a) *Durometer Hardness*—Tentative Method of Test for Indentation of Rubber by Means of the Durometer (ASTM D 676).

(b) *Tensile Strength and Elongation*—Standard Methods of Tension Testing of Vulcanized Rubber (ASTM D 412) using die C.

(c) *Load Deflection*—Tentative Methods of Test for Compression-Deflection Characteristics of Vulcanized Rubber (ASTM D 575).

(d) *Compression Set*—Method B of the Tentative Methods of Test for Compression Set of Vulcanized Rubber (ASTM D 395). Heat-treatment shall be 22 hr at 158 F or 70 hr at 212 F as specified in the tables of this specification.

Note—ASTM D 395 specifies that a standard specimen shall be a cylindrical disc ½ in. thick cut from the vulcanized rubber part by means of a sharp circular die having an inside diameter of 1.129 ± 0.001 in. Provision is also made for an alternate specimen. It is permissible to assemble a specimen having the required thickness by plying together, without cementing, thinner layers of approximately equal thickness. In this specification, the standard specimen shall be used except in cases where a plied-up specimen is agreed upon between supplier and consumer.

(e) *Heat Aging*—Standard Method of Test for Accelerated Aging of Vulcanized Rubber by the Oven Method (ASTM D 573) or Standard Method of Test for Heat Aging of Rubber by the Test-Tube Method (ASTM D 865). After the specimen has been aged and cooled, the durometer hardness, tensile strength, and elongation shall be determined in accordance with Sections 7a and 7b and the changes from the original values noted.

(f) *Oil-Immersion Tests*—Tentative Methods of Test for Changes in Properties of Rubber and Rubber-Like Materials in Liquids (ASTM D 471) using the procedure described in Section 10c of D 471 with the following specifications:

(1) Test Liquid: Petroleum-base oils No. 1 and 3 specified in ASTM D 471 shall be used.

(2) Condenser: An air condenser shall be used in all cases. This condenser shall be a glass tube 30 in. in length with a ½-in.

TABLE 3—*Physical Requirements of Synthetic-Rubber Compounds, Type S, Class SB, Oil Resistant*[a]

GRADE NO.[b]	BASIC REQUIREMENTS								REQUIREMENTS ADDED BY SUFFIX[c]						
									Suffix E-3			Suffix E-1			Suffix B
									70 hr at 212 F, ASTM No. 3 oil			70 hr at 212 F, ASTM No. 1 oil			
	Durometer hardness number	Minimum tensile strength, psi	Minimum ultimate elongation, %	Oil aged 70 hr at 212 F		Heat aged 70 hr at 212 F			70 hr at 212 F, maximum compression set, %	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Change in durometer hardness (limits)	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Change in durometer hardness (limits)	70 hr at 212 F, maximum compression set, %
				ASTM No. 3 oil	ASTM No. 1 oil	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Maximum change in durometer hardness								
				Volume change, % (limits)	Volume change, % (limits)											
*SB410	40 ± 5	1000	450	−5 +40	−20 +5	−25	−50	+20	80	−50	−50	−15 +5	−25	−50	−5 +20	60
*415	40 ± 5	1500	500	0 +40	−15 +5	−25	−50	+20	80	−50	−50	−15 +5	−25	−50	−5 +20	60
SB505	50 ± 5	500	300	0 +40	−15 +5	−25	−50	+15	75	−50	−50	−15 +5	−25	−50	−5 +15	50
510	50 ± 5	1000	350	0 +40	−15 +5	−25	−50	+15	75	−50	−50	−15 +5	−25	−50	−5 +15	50
*515	50 ± 5	1500	400	0 +60	−10 +5	−25	−50	+15	75	−60	−60	−20 +5	−25	−50	−5 +15	50
520	50 ± 5	2000	400	0 +60	−10 +5	−25	−50	+15	75	−60	−60	−20 +5	−25	−50	−5 +15	50
SB605	60 ± 5	500	200	0 +40	−15 +5	−20	−50	+15	75	−40	−40	−15 +5	−20	−40	−5 +15	50
*610	60 ± 5	1000	250	0 +40	−15 +5	−20	−50	+15	75	−40	−40	−15 +5	−20	−40	−5 +15	50
*615	60 ± 5	1500	300	0 +50	−10 +5	−20	−50	+15	75	−50	−50	−20 +5	−20	−40	−5 +15	50
620	60 ± 5	2000	350	0 +50	−10 +5	−20	−50	+15	75	−50	−50	−20 +5	−20	−40	−5 +15	50
625	60 ± 5	2500	350	0 +50	−10 +5	−20	−50	+15	75	−50	−50	−20 +5	−20	−40	−5 +15	50
SB705	70 ± 5	500	150	0 +35	−15 +5	−20	−50	+15	75	−40	−40	−15 +5	−20	−40	−5 +15	50
710	70 ± 5	1000	200	0 +35	−15 +5	−20	−50	+15	75	−40	−40	−15 +5	−20	−40	−5 +15	50
*715	70 ± 5	1500	250	0 +40	−10 +5	−20	−50	+15	75	−40	−40	−15 +5	−20	−40	−5 +15	50
720	70 ± 5	2000	250	0 +40	−10 +5	−20	−50	+15	75	−40	−40	−15 +5	−20	−40	−5 +15	50
725	70 ± 5	2500	300	0 +40	−10 +5	−20	−50	+15	75	−40	−40	−15 +5	−20	−40	−5 +15	50
730	70 ± 5	3000	300	0 +40	−10 +5	−20	−50	+15	75	−40	−40	−15 +5	−20	−40	−5 +15	50
SB805	80 ± 5	500	100	0 +30	−15 +5	−20	−50	+15	75	−40	−40	−10 +5	−20	−40	−5 +15	50
810	80 ± 5	1000	100	0 +30	−15 +5	−20	−50	+15	75	−40	−40	−10 +5	−20	−40	−5 +15	50
*815	80 ± 5	1500	125	0 +30	−10 +5	−20	−50	+15	75	−40	−40	−10 +5	−20	−40	−5 +15	50
820	80 ± 5	2000	125	0 +30	−10 +5	−20	−50	+15	75	−40	−40	−10 +5	−20	−40	−5 +15	50
SB905	90 ± 5	500	50	0 +25	−10 +5	−20	−50	+10	75	−40	−40	−10 +5	−20	−40	−5 +10	50
*910	90 ± 5	1000	100	0 +25	−10 +5	−20	−50	+10	75	−40	−40	−10 +5	−20	−40	−5 +10	50
915	90 ± 5	1500	100	0 +25	−10 +5	−20	−50	+10	75	−40	−40	−10 +5	−20	−40	−5 +10	50

[a] See Section 7 for methods of testing.
[b] The compounds marked with an asterisk are those which are most commonly used. It is suggested that these compounds be specified when possible.
[c] See Section 3.

bore fitted tightly to the immersion tube by means of a cork stopper. The bottom of the condenser tube shall project ½ in. below the stopper.

(3) Volume of Liquid: The test tube prescribed in ASTM D 471 shall be three-quarters full of liquid after the test specimens are immersed.

(4) Tensile Strength: The tensile strength of the specimen, after removal from the liquid, shall be calculated on the original unaged cross-sectional area and not according to the formula given in Section 2c of ASTM D 471.

(5) Durometer Hardness: Immediately after removal of the specimen from the cool liquid and after drying as specified, the durometer hardness number shall be determined in accordance with ASTM D 676, and the change from the original durometer hardness number noted.

(g) *Staining Tests*—The staining property shall be determined by ASTM D 925—47T.

(h) *Resilience*—This property shall be determined by ASTM D 945—48T.

8. **Sampling and Inspection**

(a) A lot, unless otherwise specified, shall consist of all products of the same composition and same grade submitted for inspection at the same time.

(b) When proof of conformance with these specifications is

TABLE 4—*Physical Requirements of Synthetic-Rubber Compounds, Type S, Class SC, Oil Resistant*[a]

	BASIC REQUIREMENTS									REQUIREMENTS ADDED BY SUFFIX[c]					
				Oil aged 70 hr at 212 F		Heat aged 70 hr at 212 F				Suffix E-3		Suffix E-1			
				ASTM No. 3 oil	ASTM No. 1 oil					70 hr at 212 F, ASTM No. 3 oil		70 hr at 212 F, ASTM No. 1 oil			Suffix B
GRADE NO.[b]	Durometer hardness number	Minimum tensile strength, psi	Minimum ultimate elongation, %	Volume change, % (limits)	Volume change, % (limits)	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Maximum change in durometer hardness	22 hr at 158 F, maximum compression set, %	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Maximum change in tensile strength, %	Maximum change in ultimate elongation, %	Change in durometer hardness (limits)	70 hr at 212 F, maximum compression set, %
SC405	40 ± 5	500	300	+60 +120	±15	−15	−40	+20	65	−75	−55	−20	−30	±10	70
410	40 ± 5	1000	400	+60 +120	±15	−15	−40	+20	65	−75	−55	−20	−30	±10	70
*415	40 ± 5	1500	500	+60 +120	±15	−15	−40	+15	65	−75	−55	−20	−30	±10	70
*420	40 ± 5	2000	500	+80 +140	−5 +15	−15	−40	+15	60	−80	−55	−30	−30	±10	70
425	40 ± 5	2500	500	+80 +140	−5 +15	−15	−40	+15	60	−80	−55	−30	−30	±10	70
SC505	50 ± 5	500	300	+50 +100	±15	−15	−40	+20	60	−70	−55	−30	−30	±10	65
510	50 ± 5	1000	300	+50 +100	±15	−15	−40	+20	60	−70	−55	−30	−30	±10	65
*515	50 ± 5	1500	350	+60 +110	−10 +15	−15	−40	+15	60	−70	−55	−30	−30	±10	65
*520	50 ± 5	2000	400	+70 +120	−5 +15	−15	−40	+15	50	−70	−55	−30	−30	±10	65
525	50 ± 5	2500	450	+80 +130	−5 +15	−15	−40	+15	50	−70	−55	−40	−30	±10	65
530	50 ± 5	3000	500	+80 +140	−5 +15	−15	−40	+15	50	−80	−55	−40	−30	±10	65
535	50 ± 5	3500	500	+90 +150	−5 +15	−15	−40	+15	50	−80	−55	−40	−30	±10	65
SC605	60 ± 5	500	300	+50 +100	−10 +15	−15	−40	+20	50	−65	−55	−30	−30	±10	65
*610	60 ± 5	1000	300	+50 +100	−10 +15	−15	−40	+15	50	−65	−55	−30	−30	±10	65
*615	60 ± 5	1500	350	+60 +110	−5 +15	−15	−40	+15	50	−65	−55	−30	−30	±10	65
*620	60 ± 5	2000	350	+60 +110	−5 +15	−15	−40	+15	50	−65	−55	−30	−30	±10	65
625	60 ± 5	2500	400	+70 +120	−5 +15	−15	−40	+15	50	−70	−55	−30	−30	±10	65
630	60 ± 5	3000	400	+80 +140	−5 +15	−15	−40	+15	50	−80	−55	−40	−30	±10	65
635	60 ± 5	3500	400	+90 +150	−5 +15	−15	−40	+15	50	−80	−55	−40	−30	±10	65
SC705	70 ± 5	500	200	+50 +100	−5 +15	−15	−40	+15	50	−65	−50	−15	−30	−5 +10	65
*710	70 ± 5	1000	200	+50 +100	−5 +15	−15	−40	+15	50	−65	−50	−15	−30	−5 +10	65
*715	70 ± 5	1500	250	+50 +100	−5 +15	−15	−40	+15	50	−65	−50	−15	−30	−5 +10	65
720	70 ± 5	2000	300	+50 +100	−5 +15	−15	−40	+15	50	−65	−50	−15	−30	−5 +10	65
725	70 ± 5	2500	300	+70 +120	−5 +15	−15	−40	+15	50	−70	−50	−20	−30	−5 +10	65
SC805	80 ± 5	500	100	+30 +80	−5 +15	−15	−40	+15	45	−45	−30	−15	−30	−5 +10	65
810	80 ± 5	1000	100	+30 +80	−5 +15	−15	−40	+15	45	−45	−30	−15	−30	−5 +10	65
*815	80 ± 5	1500	100	+30 +80	−5 +15	−15	−40	+15	45	−45	−30	−15	−30	−5 +10	65
820	80 ± 5	2000	150	+30 +80	−5 +15	−15	−40	+15	45	−45	−30	−15	−30	−5 +10	65
SC905	90 ± 5	500	50	+20 +70	−5 +15	−15	−40	+10	45	−40	−20	−15	−30	±5	65
*910	90 ± 5	1000	100	+20 +70	−5 +15	−15	−40	+10	45	−40	−20	−15	−30	±5	65
915	90 ± 5	1500	150	+20 +70	−5 +15	−15	−40	+10	45	−40	−20	−15	−30	±5	65
920	90 ± 5	2000	150	+20 +70	−5 +15	−15	−40	+10	45	−40	−20	−15	−30	±5	65

[a] See Section 7 for methods of testing.
[b] The compounds marked with an asterisk are those which are most commonly used. It is suggested that these compounds be specified when possible.
[c] See Section 3.

required, the manufacturer shall, upon request of the purchaser at the time of ordering, furnish a sufficient number of test slabs to perform the required tests. These samples shall be prepared according to ASTM D 15 as described in Section 6a. They shall be guaranteed to have equivalent cure and to be from the same run or batch of compound used in the lot.

Coolant-System Hoses (SAE R 20)

SAE Standard

Report of Nonmetallic Materials Division approved January 1944 and last revised by Nonmetallic Materials Technical Committee January 1949.

[*This SAE Standard was formulated in 1944 under the SAE-ASTM Technical Committee on Automotive Rubber. It has been used as a guide in the selection of suitable materials for use in military and commercial vehicles and passenger cars. For the purposes of simplification, coolant hoses are divided into four types as follows:*

Part I—Severe, Heavy-Duty Type—for service such as combat vehicles and heavy-duty trucks.

Part II—Moderate-Duty Type—for less exacting service such as commercial and passenger vehicles.

Part III—Heater Hose—for standard service.

Part IV—Curved Hose Connections—for service similar to either Part I or II.

In accordance with customary procedure in adopting recommendations of this Technical Committee, these product specifications for coolant hose have been approved by the SAE, and all test methods and requirements are specified in accordance with ASTM standards.

This Standard is under revision. In the course of revision, references will be brought into agreement with the latest revision of the SAE Standard on Classifications and Physical Requirements for Rubber Compounds, first published in this edition of SAE Handbook. Meantime, references in this Standard refer to parts of the Standard on Classifications and Physical Requirements for Rubber Compounds as published in the 1950 SAE Handbook.]

General Requirements

Sampling—On orders of 500 to 10,000 ft, or of more than 2000 pieces, a representative sample of sufficient size to permit one complete test against the specification shall be selected to determine conformance with the requirements of the specification.

No tests shall be required on orders of less than 500 ft or less than 2000 pieces, but materials and workmanship on such orders shall be the same as on hose tested to the specification.

Workmanship and Finish—Workmanship and finish shall be in accordance with high-grade commercial practice covering this class of work.

Packing, Marking, and Shipping—Details of packing, marking, and shipping are subject to individual arrangements between the consumer and producer.

Retests and Rejections—Any hose which fails in one or more tests shall be resampled and retested, for which purpose two additional samples shall be selected from the lot for the test or tests that failed to meet the requirements. Failure of either of the retested samples shall be cause for final rejection.

Length Tolerances, Straight Hose Only—Unless otherwise specified, the length tolerances shall be as follows:

LENGTH, IN.	TOLERANCE, IN., PLUS OR MINUS
To and including 12	1/16
Over 12 and including 24	1/8
Over 24	1/4

[1] 1950 SAE Handbook. See also ASTM D 735—43T.
[2, 3] ASTM D 380—40T, Section 5b.
[4] ASTM D 380—40T, Section 4c.

Finish on Connections—Users of coolant hose should take every precaution to obtain connections with as smooth a finish as possible.

Part I—Severe, Heavy-Duty Type (SAE R 21)

This type of hose requires the use of oil-resisting synthetic rubbers throughout to insure satisfactory performance in event oils, kerosene, or similar materials are added to the cooling system. The hose will suffer no serious damage on coming in contact with oils externally. It represents the best hose available for critical, severe, and heavy-duty service.

A—Scope—This type of hose is primarily for severe, critical, and heavy-duty service of which the diesel-locomotive application is a typical example. The hose is intended to withstand the effects of pressure systems, various present types of coolants, cold temperatures down to minus 40 F, and unskilled application to connections not particularly designed for ease of assembly with the hose.

Compounds based on two different synthetic rubbers are specified and designated Classes SB and SC. The requirements coincide insofar as possible with the SAE Standard Classifications and Physical Requirements for Rubber Compounds.[1] The tube, friction, and cover compounds in any one hose shall be based on one class of synthetic rubber, either SB or SC.

B—Construction

1. *Tube*—Minimum thickness shall be 0.062 in.[2]

2. *Reinforcement*—The reinforcement shall be multiple plies of square woven or cord fabric, or ply or plies of braided or knitted yarn, and shall be such that the hose meets the minimum burst requirements in Table 1, Section 7 and in Table 2.

3. *Cover*—Minimum thickness shall be 0.032 in., measured as the thickness from the reinforcement out.[3]

4. *Dimensions*—Two grades of hose are specified, one having a light wall and the other a heavy wall. The light-wall thickness shall be 11/64 in. minimum and 7/32 in. maximum. The heavy-wall thickness shall be 15/64 in. minimum and 9/32 in. maximum. These dimensions shall be measured at a section not including a lap. The designation for the two grades shall be "light wall" and "heavy wall" respectively.

Tolerances on inside diameter shall be plus or minus 1/64 in. for diameters through 3/4 in.; plus 1/64 and minus 1/32 in. for diameters over 3/4 and through 2 in.; plus or minus 1/32 in. for diameters over 2 in.[4]

C—Physical Tests—Tests shall be performed on sections and parts from the finished hose, the preparation of test samples to be in accordance with ASTM D 380.

Part II—Moderate-Duty Type (SAE R 22)

A—Scope—This type of hose is for moderate duty or normal service. Class RN is intended for moderate service and Class RS is intended for normal service. Provision is made for the use of Class SC compounds where an oil-resistant tube is required for less severe service than would be required of the heavy-duty type (Part I of this Standard).

(Note—When desired, hose with one class of material in the tube and another in the cover may be obtained; for example: Class SC tube and Class RN cover. In such cases the physical

TABLE 1—*Test Requirements for SAE R 21*

	REFER PART	CLASS SB		CLASS SC	
		Tube	Cover	Tube	Cover
1. *Original Properties*					
a—Durometer	V-2	55 to 75	—	55 to 75	—
b—Tensile, psi, min	V-3	1250	1000	1250	1000
c—Elongation, %, min	V-3	250	225	250	225
2. *Oven Aging (Change)*	V-4				
a—Durometer, points		0 to +20	—	0 to +20	—
b—Tensile, %, max		−20	−20	−15	−15
c—Elongation, %, max		−60	−60	−50	−50
3. *Oil Immersion (Change)*	V-5				
a—Volume, %		−5 to +25	−5 to +25	50 to 100	50 to 100
b—Tensile, %, max		−20	−20	−60	−60
4. *Coolant Immersion (Change)*	V-6				
a—Vo'ume, %		0 to 20	—	0 to 20	—
b—Durometer, points		−10 to +10	—	−20 to +10	—
c—Tensile, %, max		−20	—	−30	—
d—Elongation, %, max		−40	—	−40	—
5. *Adhesion (psi)*	V-7				
a—Tube to ply, min		12	—	12	—
b—Ply to ply, min		12	—	12	—
6. *Cold Flexibility*	V-8	The tube and cover of classes SB and SC shall pass the cold flexibility test at −40 F.			
7. *Burst*	V-9	See Table 2.			

TABLE 2—*Minimum Burst-Test Values, Psi*

INSIDE DIAMETER, IN.	LIGHT WALL	HEAVY WALL	INSIDE DIAMETER, IN.	LIGHT WALL	HEAVY WALL
3/8	475	—	1 1/2	200	450
1/2	425	—	1 3/4	175	400
5/8	360	—	2	150	350
3/4	325	—	2 1/4	125	350
1	275	—	2 1/2	100	300
1 1/8	250	—	2 3/4	90	250
1 1/4	225	500	3	75	250

properties specified for the respective parts shall apply. Adhesion requirements shall be based on the class of material for which the lower value is specified.)

B—Construction

1. *Tube*—Minimum thickness shall be 0.062 in.[5]

2. *Reinforcement*—The reinforcement shall be multiple plies of square woven or cord fabric, or ply or plies of braided or knitted yarn, and shall be such that the hose meets the minimum burst requirements listed in Table 3, Section 7.

3. *Cover*—Minimum thickness shall be 0.032 in., measured as the thickness from the reinforcement out.[6]

4. *Dimensions*—Two grades of hose are specified, one having a light wall and the other a heavy wall. The light-wall thickness shall be 1 1/64 in. minimum and 7/32 in. maximum. The heavy wall shall be 1 5/64 in. minimum and 9/32 in. maximum. These dimensions shall be measured at a section not including a lap. The designation for the two grades shall be "light wall" and "heavy wall" respectively.

Tolerances on inside diameter shall be plus or minus 1/64 in. for diameters through 3/4 in.; plus 1/64 and minus 1/32 in. for diameters over 3/4 and through 2 in.; plus or minus 1/32 in. for diameters over 2 in.[7]

C—Physical Tests—Details for laboratory tests are shown under Part V, Physical Test Procedures. Tests are intended to be performed on sections and parts from the finished hose, the preparation of test samples to be in accordance with ASTM D 380.

Part III—Heater Hose (SAE R 23)

A—Scope—This type of hose is used in connecting hot-water heaters into the coolant circulating systems of ground vehicles. Class RN is intended for moderate service and Class RS is intended for normal service. Provision is made for the use of Class SC compounds where an oil-resistant tube is required.

(Note—When desired, hose with one class of material in the tube and another in the cover may be obtained; for example: Class SC tube and Class RN cover. In such cases the physical properties specified for the respective parts shall apply. Adhesion

[5, 6] ASTM D 380—40T, Section 5b.
[7] ASTM D 380—40T, Section 4c.

TABLE 3—*Test Requirements for SAE R 22*

	REFER PART	CLASS SC TUBE	CLASS RS		CLASS RN	
			Tube	Cover	Tube	Cover
1. *Original Properties*						
a—Durometer	V-2	55 to 75	55 to 75	—	55 to 75	—
b—Tensile, psi, min	V-3	800	800	800	500	400
c—Elongation, %, min	V-3	250	250	225	175	150
2. *Oven Aging (Change)*	V-4					
a—Durometer, points		0 to 20	0 to 20	—	0 to 15	—
b—Tensile, %, max		−15	−20	−20	−25	−25
c—Elongation, %, max		−50	−60	−60	−50	−50
3. *Oil Immersion (Change)*	V-5					
a—Volume, %		50 to 100	—	—	—	—
b—Tensile, %, max		−60	—	—	—	—
4. *Coolant Immersion (Change)*	V-6					
a—Volume, %, max		0 to 25	0 to 25	—	0 to 20	—
b—Tensile, %, max		−30	−40	—	−50	—
c—Elongation, %, max		−40	−40	—	−40	—
5. *Adhesion (psi)*	V-7					
a—Tube to ply, min		[a]	10	—	8	—
b—Ply to ply, min			12	—	8	—
6. *Cold Flexibility*	V-8	The tube and cover of all classes shall pass the cold flexibility test at −40 F.				
7. *Burst*	V-9					
Minimum burst values		See Table 2.				

[a] See note under Part II, Section A—Scope.

requirements shall be based on the class of material for which the lower value is specified.)

B—Construction

1. *Tube*—Minimum thickness 0.062 in.[8]

2. *Reinforcement*—The reinforcement shall be multiple plies of wrapped fabric, or ply or plies of braided or knitted cotton yarn and shall be such as to meet the minimum burst requirements in Table 4, Section 6.

3. *Cover*—Minimum thickness 0.032 in.[9]

4. *Dimensions*—This hose shall be made in a nominal $\frac{5}{8}$-in. inside diameter by $1\frac{5}{16}$-in. outside diameter. The tolerance on inside diameter shall be plus $\frac{1}{64}$ in. and minus $\frac{3}{64}$ in., and on outside diameter shall be plus or minus $\frac{1}{32}$ in.[10]

C—Physical Tests—Details for laboratory tests are shown under Part V, Physical Test Procedures. Tests are intended to be performed on sections and parts from the finished hose. The preparation of test samples is in accordance with ASTM D 380.

Part IV—Knitted or Braided Curved Hose Connections (SAE R 24)

A—Scope—This part covers curved hose connections for circulating systems of ground vehicles. Classes SC, RS, and RN only are covered in this application. Class SC is recommended for severe, heavy-duty service; Class RS, for moderate-duty service; and Class RN, for the most moderate service. Curved hose connections produced from plies of square woven fabric should conform to Parts I or II of this Standard.

(Note—When desired, hose with one class of material in the tube and another in the cover may be obtained; for example: Class SC tube and Class RN cover. In such cases the physical properties specified for the respective parts shall apply. Adhesion requirements shall be based on the class of material for which the lower value is specified.)

B—Construction

1. *Tube*—Minimum thickness 0.062 in.[11]

2. *Reinforcement*—The reinforcement shall consist of one or more plies of knitted or braided cotton yarn and shall be such that the hose will meet the minimum burst requirements in Table 5, Section 7.

3. *Cover*—Minimum thickness 0.032 in.[12]

4. *Dimensions*—One grade of hose shall be specified having a wall thickness of $1\frac{1}{64}$ in. minimum and $\frac{7}{32}$ in. maximum. On hose with expanded or enlarged ends, the wall thickness can be $\frac{5}{32}$ in. minimum.

Tolerances on the inside diameter shall be plus or minus $\frac{1}{32}$ in.

C—Physical Tests—Tests shall be performed on sections and

[8, 9] ASTM D 380—40T, Section 5b.
[10] ASTM D 380—40T, Section 4c.
[11, 12] ASTM D 380—40T, Section 5b.

TABLE 4—*Test Requirements for SAE R 23*

	REFER PART	CLASS SC	CLASS RS		CLASS RN	
		Tube	Tube	Cover	Tube	Cover
1. *Original Properties*	V-3					
a—Tensile, psi, min		800	800	800	500	400
b—Elongation, %, min		250	250	225	175	150
2. *Oven Aging (Change)*	V-4					
a—Tensile, %, max		−15	−20	−20	−25	−25
b—Elongation, %, max		−50	−60	−60	−50	−50
3. *Coolant Immersion (Change)*	V-6					
a—Volume, %		0 to 25	0 to 25	—	0 to 20	—
b—Tensile, %, max		−30	−50	—	−50	—
4. *Adhesion (psi)*	V-7					
a—Tube to ply, min		—	6	—	4	—
b—Ply to ply, min		—	6	—	4	—
5. *Cold Flexibility*	V-8	The tube and cover of all classes shall pass the cold flexibility test at −40 F.				
6. *Burst* Minimum	V-9	All classes, 140 psi.				

parts from the finished hose. The preparation of test samples are to be in accordance with ASTM D 380.

Part V—Physical Test Procedures

1. **Specification for Immersion Liquids**

(a) Alcohol—Special denatured alcohol Grade No. 1 or an equivalent mixture.

(b) Oil—ASTM No. 3 Oil.[13]

(c) Ethylene Glycol—This shall be what is termed "Refined Grade of Ethylene Glycol" and shall conform to the following requirements:

Acidity—Not more than 0.01% as acetic acid.

Specific Gravity—1.1150 to 1.1158 at 20 C.

Color—Water white.

Boiling Range—(760 mm) above 210 C, none; below 190 C,

[13] ASTM D 471—43T, Table 1.

TABLE 5—*Test Requirements for SAE R 24*

	REFER PART	CLASS SC		CLASS RS		CLASS RN	
		Tube	Cover	Tube	Cover	Tube	Cover
1. *Original Properties*							
a—Durometer	V-2	60 to 80	—	60 to 80	—	60 to 80	—
b—Tensile, psi, min	V-3	1000	800	800	400	500	400
c—Elongation, %, min	V-3	200	150	200	150	150	150
2. *Oven Aging (Change)*	V-4						
a—Durometer, points		0 to 20	—	0 to 20	—	0 to 15	—
b—Tensile, %, max		−15	−25	−20	−25	−25	−25
c—Elongation, %, max		−50	−55	−55	−60	−55	−50
3. *Oil Immersion (Change)*	V-5						
a—Volume, %		50 to 100	50 to 100	—	—	—	—
b—Tensile, %, max		−60	−60	—	—	—	—
4. *Coolant Immersion (Change)*	V-6						
a—Volume, %		0 to 25	—	0 to 25	—	0 to 30	—
b—Tensile, %, max		−30	—	−50	—	−50	—
5. *Adhesion (psi)* Tube to ply, min	V-7	10	—	8	—	6	—
6. *Cold Flexibility*	V-8	The tube and cover of all classes shall pass the cold flexibility test at −40 F.					
7. *Burst* Minimum	V-9	90 psi for sizes to and including 1½ in. ID, and 80 psi for 1¾ in. ID.					

none; below 195 C, not more than 5%; below 202 C, not less than 95%.

Water—Not more than 0.5% by weight.

Ash—Not more than 0.005 gm per 100 cc.

Odor—Mild, nonresidual.

Average Weight—9.28 lb per gal at 20 C.

2. **Durometer Hardness**—This is to be measured with an instrument according to Proposed Tentative Method of Test for Indentation of Rubber by Means of the Durometer,[14] except that the reading shall be made immediately. Tests shall be made on not less than ¼-in. thickness to be made up by laying together smoothly buffed layers of the compound.

3. **Tensile (Elongation)**—Test according to ASTM D 380, Sections 8, 9, 10, and 11. The maximum per cent change in elongation shall be applied as a percentage of the actual original per cent elongation determined for the particular sample. Example: If the original requirement is 250% minimum elongation, and the maximum per cent change permitted in elongation after oven aging is −60, and if the actual original elongation of the material is found to be 350%, then the minimum elongation permitted after the aging test is 140%.

4. **Oven Aging**—This shall conform to the SAE Standard Classifications and Physical Requirements for Rubber Compounds, Oven Aging[15] except that test specimens shall be prepared in accordance with ASTM D 380, Section 9. The aging conditions are 70 hr at 212 F in circulating air for Classes SB, SC, and RS; and 70 hr at 158 F in circulating air for Class RN.

5. **Oil Immersion**—Test to conform to the SAE Standard Classifications and Physical Requirements for Rubber Compounds,[16] Liquid Aging, except that the test specimens shall be in accordance with ASTM D 380, Section 23a in the case of the volume-change test, and with ASTM D 380, Section 9 in the case of the strength-deterioration test.

Three tensile-test samples and two volume-change samples shall be placed in a glass test tube having an outside diameter of 38 mm and an overall length of 300 mm fitted tightly with a cork stopper and a reflux condenser. The tube shall be three-quarters full of test fluid. The test shall be run for 70 hr at 212 F.

The tensile strength of the specimens after removal from the liquid, ASTM D 471, Section 9c, shall be calculated on the original unaged cross-sectional area and not according to the formula given in Section 10c of ASTM D 471. Measurement and calculation of volume change shall be in accordance with Section 8a and 10a, ASTM D 471.

6. **Coolant Immersion**—Per cent swell, tensile, and durometer shall be observed after 70-hr immersion in the following mixture maintained at the boiling point under a water-cooled reflux condenser:

⅓ by volume, distilled water

⅓ by volume, alcohol (see Part V, Section 1a)

⅓ by volume, ethylene glycol (see Part V, Section 1c)

All other details of test are the same as under Part V, Section 5.

Test specimens shall be in accordance with ASTM D 380, Section 23a in the case of the swelling test, and Section 9 in the case of the strength-deterioration test. Measurements of tensile and durometer shall be made in accordance with the standard ASTM D 471, Section 9 and measurements of volume change in accordance with Section 9a of the same reference.

7. **Adhesion**—Test according to ASTM D 413, Sections 6 and 7b. Wrapped fabric hose is to be separated one ply from the adjacent part. Braided or knitted constructions may be separated as two or more plies from the adjacent part. In Part IV, the adhesion values apply to rubber-to-rubber contacts only.

8. **Cold Flexibility**—The following procedure is in accordance with the SAE Standard Classifications and Physical Requirements for Rubber Compounds.[17]

(a) Time of exposure to low temperature to be 5 hr.

(b) Temperature, minus 40 F.

(c) Medium, dry air.

(d) Specimens 4 x 0.25 x tube or cover thickness, or 0.10 in. maximum. The specimen shall be placed in an unrestrained loop position between two jaws 2 in. wide and 2½ in. apart. After cold-temperature exposure and while still in the cold chamber, the jaws shall be rapidly brought together until they are 1 in. apart. The specimen shall not fracture and shall not show any cracks, checks, or breaks.

9. **Burst**—This test shall be performed on a straight length for Parts I, II, and III in accordance with ASTM D 380, Sections 15, 16, and 17, except that the length tested shall be 10 in. with 8 in. of free length.

For Part IV, the same reference applies, except that the test shall be performed on the individual curved connections with one end free and unrestrained and the rate of application of pressure shall be not less than 300 nor more than 1000 psi per min.

[14] ASTM D 676—42T.

[15] 1950 SAE Handbook, SAE Standard Classifications and Physical Requirements for Rubber Compounds, Methods of Test, Oven Aging. See also ASTM D 735—43T, Section 8f.

[16] 1950 SAE Handbook, SAE Standard Classifications and Physical Requirements for Rubber Compounds, Methods of Test, Liquid Aging. See also ASTM D 735—43T, Section 8g.

[17] 1950 SAE Handbook, SAE Standard Classifications and Physical Requirements for Rubber Compounds, Methods of Test, Low Temperature Brittleness. See also ASTM D 736—43T.

Fuel and Oil Hoses (SAE R 30)

SAE Recommended Practice

Report of Nonmetallic Materials Division approved January 1946 and last revised by Nonmetallic Materials Technical Committee January 1949.

[This SAE Standard was formulated by SAE-ASTM Technical Committee on Automotive Rubber.]

Coupled Metal-Lined Hose (SAE R 31)

Scope—This specification covers one type and one style of hose assemblies for use with gasoline, oil, or diesel fuel.

Hose Construction—The hose shall consist of a flexible spiral metal line of narrow profile with interlocking edges. The sealing layer shall be either a suitable rubber or synthetic compound. The reinforcement shall be one or more plies of braided cotton or other suitable material. The reinforcement shall be protected by a flexible lacquer or cement. Dimensions and tolerances are listed in Table 1.

TABLE 1—*Dimensions and Tests for SAE R 31*

DIAMETERS, IN.		PROOF TEST PRESSURE, PSI		MINIMUM BURST PRESSURE, PSI	MINIMUM TENSILE TEST, LB	MINIMUM BEND DIAMETER, IN.
Inside	Outside	Air	Water			
5/32	0.395 0.425	15	100	700	100	4
3/16	0.410 0.440	15	100	700	125	5
1/4	0.480 0.515	15	100	700	150	6
5/16	0.561 0.596	15	100	700	150	7
3/8	0.690 0.730	15	100	700	150	8

Types of Tests—The hose assemblies shall be subjected to two types of tests: qualification and inspection.

Qualification Tests—Ten hose assemblies shall be submitted for qualification. The following qualification tests shall be performed: (1) leakage unaged assemblies; (2) burst-pressure test; (3) tensile strength aged assemblies; (4) cold flexibility test (aged and unaged); (5) vibration test; (6) corrosion test (hose and fittings).

Inspection Tests—The inspection tests are as follows: (1) visual inspection; (2) proof-pressure test; (3) tensile test; (4) burst-pressure test; (5) swelling test.

Retests and Rejections—Any lot of hose assemblies which fail in any test shall be resampled and retested. Twice as many samples shall be selected. Failure of the hose assemblies on the retest shall be cause for final rejection.

Methods of Testing—Qualification Test

Leakage Test—All the assemblies shall be held for one to three minutes under air pressure of 15 psi or hydrostatic pressure of 100 psi. If air is used the assemblies shall be tested immersed in water. There shall be no leakage.

Burst-Pressure Test—Two assemblies shall be submitted to hydrostatic pressure which shall be increased at the rate of 5000 psi per min until failure occurs. The hose shall not burst or the fittings leak or blow off at pressures lower than those listed as minimum in Table 1.

Tensile Test—Two assemblies shall be aged for 70 hr in an oven, the temperature of which is 212 ± 2 F, cooled to room temperature, and tensile tested. The assemblies shall be kept filled with ASTM Test Oil No. 3 during the aging period. The rate of movement of the jaws shall not be greater than 4 in. per min. The assemblies shall not fail or the fittings pull off at less than the minimum value in Table 1.

Cold Flexibility Test—Two assemblies shall be held for 70 hr in an oven at 212 ± 2 F. The assemblies shall be kept filled with ASTM test oil. After aging, the samples shall be allowed to cool to room temperature, and then placed in a cold box and held for 5 hr at −40 F. The assemblies shall be bent around a mandrel, the diameter of which is given in Table 1, in one-half second. There shall be no cracking of the sealing layer as indicated by testing hydrostatically at 100 psi.

Vibration Test—Two coupled assemblies shall be placed in a vibration-testing machine and subjected to the following test for a minimum of 50 hr:

Length of sample: 8 in. minimum
Frequency of vibration: 1100 cpm ± 10 cycles
Total amplitude: $1\frac{5}{16}$ in.
Arrangement: 1½ in. offset at 90 deg to direction of stroke
Initial slack: 3/16 in.

During the test either ASTM Test Oil No. 1 or 3 shall be circulated through the hose at a temperature of 250 F and 45 psi.

Corrosion Test—The corrosion test shall be conducted according to ASTM B 117 and the period shall be 48 hr. There shall be no evidence of corrosion or other deterioration at the expiration of this test. Continuous visible leakage shall be considered as a failure.

Methods of Testing—Inspection Test

Visual Inspection—All assemblies shall be inspected to see that the correct fittings are properly applied.

Proof-Pressure Test—5% of each lot of assemblies shall be subjected to the proof-pressure test. The pressures are listed in Table 1. There shall be no leakage.

Tensile Test—Two assemblies shall be selected from each lot of 100 or more pieces up to 10,000 pieces and tensile tested. For lots of more than 10,000 pieces, two samples shall be selected for each 10,000 or fraction thereof. The assemblies shall not be aged. There shall be no failures at less than the minimum requirements of Table 1.

Burst-Pressure Test—Two assemblies from each lot selected as stated in Inspection Tensile Test shall be burst. The failures shall not occur at values less than those given in Table 1.

Swelling Test—Two assemblies shall be selected from each lot of 100 or more pieces up to 10,000 pieces and tested for swelling as follows:

Hose shall be filled with standard test fuel SR-10 (Di-iso-

butylene) for a period of 22 hr at room temperature. Any evidence of visible swelling clogging the hose bore shall be considered a failure.

Coupled and Uncoupled Synthetic-Rubber Tube and Cover (SAE R 32)

Scope—This specification covers fuel and oil hose, coupled and uncoupled, for automotive applications. The construction includes cotton reinforcement or other suitable reinforcing material in single- or two-braid styles or multiple plies of woven fabric.

The hose is intended to withstand the effects of straight run gasoline and fuel containing up to 40% aromatics, as well as diesel fuels and lubricating oils. It is further required that the hose shall perform satisfactorily at temperatures down to −40 F and shall assemble satisfactorily with fittings and couplings.

Hose Construction—*Type 1*—The construction of this hose embodies a smooth-bore tube of flexible material, reinforced with one braid or multiples of woven fabric, and finished with polychloroprene cover. This type is made in two styles: Style 1, SB Tube; and Style 2, SC Tube.

Type 2—The construction of this hose embodies a smooth-bore tube of flexible material, reinforced with two braids or multiples of woven fabric, and finished with a polychloroprene cover. This type is made in two styles: Style 1, SB Tube; and Style 2, SC Tube.

Dimensions—Dimensions and tolerances are shown in Table 2.

TABLE 2—*Dimensions and Tolerances for SAE R 32*

SIZE, IN.	INSIDE DIAM, IN.	TYPE I, OUTSIDE DIAM, IN.		TYPE II, OUTSIDE DIAM, IN.	
	Tolerance, plus or minus	Min	Max	Min	Max
1/8	1/64	21/64	3/8	7/16	1/2
3/16	1/64	25/64	7/16	1/2	9/16
1/4	1/64	29/64	1/2	9/16	5/8
5/16	1/64	33/64	9/16	5/8	11/16
3/8	1/64	37/64	5/8	11/16	3/4
7/16	1/32	—	—	3/4	13/16
1/2	1/32	23/32	25/32	13/16	7/8
5/8	1/32	27/32	29/32	15/16	1
3/4	1/32	1 1/16	1 1/8	1 1/16	1 1/8
7/8	1/32	—	—	1 3/16	1 1/4
1	1/32	1 9/32	1 3/8	1 9/32	1 3/8
1 1/8	1/32	—	—	1 1/2	1 5/8
1 1/4	1/32	—	—	1 5/8	1 3/4
1 3/8	1/32	—	—	1 3/4	1 7/8
1 1/2	1/32	—	—	1 7/8	2
1 5/8	1/32	—	—	2	2 1/8
1 3/4	1/32	—	—	2 1/8	2 1/4
2	1/32	—	—	2 3/8	2 1/2

Retests and Rejections—Any hose or assembly which fails in one or more tests shall be resampled and retested. Twice the number of specimens shall be selected from the lot in question for any retests, and failure of any of the retested samples shall be cause for rejection.

Tests—Procedures described by ASTM D 380 are to be followed wherever applicable.

Tests—Qualification Tests—For qualification tests, one 25-ft length or ten assemblies of each size to be qualified shall be furnished. Hose and hose assemblies in order to qualify under this specification must meet the requirements of the following tests: (1) contraction test followed by bursting-strength test; (2) vacuum collapse; (3) cold flexibility; (4) tensile and elongation, tube and cover; (5) dry heat; (6) volume change of tube and cover or decrease in inside diameter; (7) adhesion.

In addition to the above, hose assemblies shall be subjected to qualification tests as follows: (8) proof test; (9) tensile strength; (10) leakage; (11) vibration; (12) corrosion; (13) visual.

Tests—Frequency of Testing for Inspection—On uncoupled hose, tests shall be conducted on samples representing each lot of 500 to 10,000 ft. Where a lot is 500 ft or less, no tests shall be conducted, but materials and workmanship shall be the same on such lots as on hose previously qualified under this specification.

On coupled hose lots of from 100 to 10,000 pieces not less than two assemblies shall be subjected to all inspection tests except the visual test, which shall apply to 100% of the assemblies.

Tests—Inspection Tests—On uncoupled hose, these inspection tests shall apply: (1) vacuum collapse; (2) contraction and burst; (3) cold flexibility; (4) adhesion.

On coupled-hose assemblies, these tests shall apply: (5) proof pressure; (6) tensile strength (unaged); (7) visual (100%); (8) burst.

Tests—Requirements

Contraction Test—Tests for contraction shall be conducted in accordance with ASTM D 360 except that the original measurement shall be made at 0 psi pressure. The contraction shall be determined at the pressures specified in Table 3. Requirements are as follows:

Type I: All sizes, 5% maximum.

Type II: Up to 1/2-in. inside diameter hose, 8% maximum; 1/2-in. inside diameter hose and larger, 6% maximum.

Burst Test—The minimum bursting strength shall be as specified in Table 3.

TABLE 3—*Burst and Contraction Tests for SAE R 32*

INSIDE DIAMETER, IN.	MINIMUM BURST TEST, PSI	CONTRACTION-TEST PRESSURES, LB
1/2 and under	700	115
Over 1/2 to 1 inclusive	500	85
Over 1 to 1 1/2 inclusive	400	65
Over 1 1/2 to 2 inclusive	250	40

Vacuum Collapse—Type 1 hose, if less than 1/2-in. inside diameter, shall be subjected to 20 in. of mercury vacuum; 1/2-in. inside diameter hose shall be subjected to 10 in. of mercury vacuum.

Type 2 hose, if less than 5/8-in. inside diameter, shall be subjected to 20 in. of mercury vacuum. Hose 5/8- through 1-in. inside diameter shall be subjected to 10 in. of mercury vacuum; sizes greater than 1-in. inside diameter shall be excluded from the vacuum test.

During the vacuum test described for hose of Types I and II, a 3-ft length of hose or a hose assembly shall be held in a straight

line, and no diameter shall decrease by more than 20% during application of vacuum for 15 and not over 30 sec.

Cold Flexibility—Hose ¾-in. inside diameter and under with or without couplings shall be used for this test. One sample shall be immersed in petroleum-base oil having an aniline point 159 ± 2 F and a Saybolt Universal viscosity of 155 ± 5 sec at 100 F for 70 hr at 212 F. The aged and unaged samples shall then be subjected to a temperature of −40 F for a period of 5 hr, after which the hose shall be flexed in the cold chamber through 180 deg from the centerline to a diameter of ten times the maximum outside diameter of the hose. This flexing shall be within 4 sec. The hose shall not fracture and shall not show any cracks, checks, or breaks in the tube or cover. This may be determined by reapplication of proof pressure specified in Table 3.

Hose over ¾-in. inside diameter shall have specimens 4 x 0.25 x tube or cover thickness or 0.10 in. maximum cut from tube and cover. One set of samples shall be unaged. The other set of samples shall be completely immersed in oil for 70 hr at 212 F. The unaged and aged specimens shall then be subjected to a temperature of −40 F for a period of 5 hr, in an unrestrained loop position between two jaws 2 in. wide and 2½ in. apart. At the end of 5 hr and while still in cold chamber, the jaws shall be rapidly brought together until they are 1 in. apart. The specimen shall not fracture and shall not show any cracks, checks, or breaks.

Tensile and Elongation

Original tensile strength of cover: 1000 psi minimum
Original tensile strength of tube: 1200 psi minimum
Original elongation of cover: 200% minimum
Original elongation of tube: 250% minimum

Dry Heat—After oven aging for 70 hr at a temperature of 212 F, the reductions in tensile strength and elongation of specimens taken from the tube and cover shall not exceed the following values:

SB Tube: Original tensile, minus 20%
Original elongation, minus 60%
SC Tube: Original tensile, minus 15%
Original elongation, minus 50%

Volume Change—After 70-hr immersion in ASTM Test Oil No. 3 at 212 F, specimens shall not exceed the following values:

SB Tube: Volume change, −5% to +25%
SC Tube and Cover: Volume change, +50% to +100%

Decrease in Inside Diameter—This test may be substituted for volume-change measurement for sizes ½-in. inside diameter and smaller, or in other instances where suitable test specimens for volume change cannot be secured.

After 70-hr immersion in ASTM Test Oil No. 3 at 212 F, the inside-diameter change in any hose shall not exceed the following:

SB Tube: 5% to −10% of original inside diameter
SC Tube: 0% to −20% of original inside diameter

Adhesion Test—This test shall apply to all hose. The minimum load required to separate the tube and cover from adjacent plies shall be as follows:

TUBE	TYPE I, LB	TYPE II, LB
SB	4	12 throughout
SC	8	

Proof Test—Before shipment by the vendor a minimum of 10% of the assemblies shall be tested at 50% of the minimum burst specified in Table 3 for a period of not less than 30 sec nor more than 60 sec. Hose assemblies showing leaks under this test must be rejected and such a failure will cause all hose in the lot to be 100% tested.

Tensile Test of Assembly—The hose complete with fittings shall be dry-air aged at 212 F for 70 hr and then permitted to rest at room temperature for 2 hr. The hose assembly shall withstand, after the aging test, a minimum pull of 100 lb on sizes up to and including the ¼-in. size. All other sizes over ¼-in. inside diameter shall withstand 150 lb.

Leakage Test—Coupled hose shall show no leakage under a hydrostatic pressure of 70% of the minimum burst specified in Table 3 following an aging period of 70 hr at 212 F oven temperature. The pressure shall be held for a period of not less than 5 min or more than 7 min.

Vibration Test—Two coupled assemblies shall be placed in a vibration-test machine and subjected to the following test for a minimum of 200 hr without leakage or failure:

Inside diameter: ⅜ and under only
Length of sample: 8 in. minimum
Frequency of vibration: 1100 cpm ± 10 cycles
Total amplitude: 15/16 in.
Arrangement: 1½ in. offset at 90 deg to direction of stroke
Initial slack: 3/16 in.

During the tests No. 1 or No. 3 ASTM test oil at 250 F and 45 psi pressure shall be circulated through the hose. Continuous visible leakage shall be considered as a failure.

Corrosion Test—The assembly shall be tested in accordance with ASTM B 117. The period shall be 48 hr. There shall be no evidence of corrosion or other deterioration at the expiration of this test.

Braided Reinforcement Lacquer- or Cement-Covered Hose (SAE R 33)

Scope—This specification covers one type, two styles of hose suitable for use with gasoline, oil, and diesel fuel. This hose may be either coupled or uncoupled.

Hose Construction—The hose shall consist of a synthetic tube (Style 1-SB, Style 2-SC), a ply or plies of braided cotton, or other suitable reinforcing material the outside layer of which is coated with suitable gasoline- and oil-proof flexible lacquer or cement. Dimensions and tolerances are listed in Table 4.

Type of Test—The hose or assemblies shall be subjected to two types of test: qualification and inspection.

Qualification Tests—Twenty five feet of hose or ten assemblies shall be submitted for qualification. The qualification tests are as follows: (1) tensile strength of tube (hose); (2) elongation of tube (hose); (3) leakage test unaged (assembly); (4) leakage test aged (assembly); (5) burst-pressure test unaged (assembly); (6) tensile test aged (assembly); (7) volume change; (8) vibration life (assembly); (9) cold flexibility aged (hose); (10) corrosion test (fittings); (11) vacuum-collapse test (assemblies); (12) shrinkage test.

Inspection Tests—The inspection tests are outlined below and are for: (1) visual inspection of fittings and hose (100%), assemblies; (2) leakage test (5%), assemblies; (3) tensile test (2 assemblies) unaged; (4) burst-pressure test (2 assemblies); (5) proof-pressure test (hydrostatic) uncoupled hose (5%).

Retests and Rejections—Any sample of hose or lot of hose assemblies which fails in any test shall be resampled and retested

and twice as many samples shall be selected. Failure of the hose or the hose assemblies on the retest shall be cause for final rejection.

TABLE 4—*Dimensions and Tolerances for Uncoupled Hose, SAE R 33*

INSIDE DIAMETER, IN., ± 0.015	OUTSIDE DIAMETER, IN.	HYDROSTATIC PROOF PRESSURE, PSI	MINIMUM BURST PRESSURE, PSI	MINIMUM TENSILE TEST, LB	MINIMUM BEND DIAMETER, IN.
3/16	0.360 0.390	800	2000	100	4
1/4	0.420 0.450	650	1600	125	4 1/2
5/16	0.505 0.535	500	1200	125	5
3/8	0.635 0.665	350	900	150	6 1/2
1/2	0.760 0.790	300	750	150	7 1/2
5/8	0.922 0.969	250	650	150	9 1/2

Methods of Testing—Qualification Tests

Tensile and Elongation of Tube—The tests for the tensile strength and the elongation of the tube shall be performed as outlined in ASTM D 380 Sections 8, 9, 10, 11. The tensile strength of the tube shall be not less than 1200 psi, and the elongation of the tube shall be not less than 250%.

Leakage Test Unaged Assemblies—All the assemblies shall be held from 3 to 5 min under 400-lb air pressure for sizes 3/16 in. through 3/8 in. and 300 lb for all sizes over 3/8 in. A hydrostatic-pressure test may be used in lieu of the air test at pressures specified in Table 4. There shall be no leakage.

Leakage Test Aged Assemblies—Two assemblies shall be immersed in or kept filled with ASTM Test Oil No. 3 for 70 hr at 212 ± 2 F and subjected to the leakage test required under Qualification Tests. There shall be no leakage.

Burst-Pressure Test—Two assemblies shall be submitted to hydrostatic pressures which shall be increased at the rate of 1000 psi per min until failure occurs. The hose shall not burst, the fittings leak, or blow off at pressures lower than those listed as minimum in Table 4.

Tensile Test—Two assemblies shall be aged for 70 hr in an oven, the temperature of which is 212 ± 2 F, cooled to room temperature, and tensile tested. The rate of movement of the jaws shall be not greater than 4 in. per min. The assemblies shall not fail or the fittings pull off at less than the minimum values in Table 4.

Volume Change—After 70-hr immersion in ASTM Test Oil No. 3 at 212 F, specimens shall not exceed the following values:

SB Tube: volume change, −5% to +25%

SC Tube: volume change, +50% to +100%

Vibration Test—Two coupled assemblies shall be placed in a vibration testing machine and subjected to the following test for a minimum of 200 hr:

Length of sample: 8 in. minimum

Frequency of vibration: 1100 cpm ± 10 cycles

Total amplitude: 15/16 in.

Arrangement: 1 1/2 in. offset at 90 deg to direction of stroke

Initial slack: 3/16 in.

During the test either ASTM Test Oil No. 1 or 3 shall be circulated through the hose at a temperature of 250 F and 45 psi. Continuous visible leakage shall be considered as a failure.

Cold Flexibility—Two pieces of hose shall be held for 70 hr in an oven at 212 ± 2 F. The samples shall be allowed to cool to room temperature, and then placed in a cold box and held for 5 hr at −40 F. These pieces of hose shall be bent 180 deg around a mandrel of the diameters given in Table 4 in 1/2 sec. There shall be no cracking of the inner tube or covering.

Corrosion Test—The assembly shall be tested in accordance with ASTM B 117 for 48 hr. There shall be no evidence of corrosion or other deterioration at the expiration of this test.

Vacuum-Collapse Test—Two assemblies shall be subjected to a vacuum of 20 in. of mercury and the reduction in outside diameter shall not exceed 20% of the original diameter during application of vacuum for 15 and not over 30 sec. Test shall be conducted with hose in a straight position.

Shrinkage Test—The hose shall be measured at 1/6 of the minimum burst and at 0 pressure. The shrinkage in length from 0 pressure shall not exceed 8%.

Methods of Testing—Inspection Tests

Visual Inspection—All assemblies shall be inspected to see that the correct fittings are properly applied.

Proof-Pressure Test—5% of each lot of assemblies shall be subjected to proof-pressure test. The pressures are listed in Table 4. There shall be no leakage.

Proof-Pressure Test, Unassembled Hose—50% of all production shall be subjected to the hydrostatic proof-pressure test specified in Table 4.

Tensile Test—Two assemblies shall be selected from each lot of 100 or more pieces up to 10,000 pieces and tensile tested. For lots of more than 10,000 pieces, two samples shall be selected for each 10,000 or fraction thereof. The assemblies shall not be aged. There shall be no failures at less than the minimum requirement of Table 4.

Burst-Pressure Test—Two assemblies from each lot selected as stated in Inspection Test No. 3 shall be burst. The failure shall not occur at values less than those given in Table 4.

Synthetic-Rubber, Wire-Reinforced, Circular-Woven Type with Lacquer Cover (SAE R 34)

Scope—This specification covers a wire-reinforced, lacquer-covered, circular-woven type of fuel and oil hose for automotive applications.

Hose Construction—The hose consists of an inner tube or lining of Class SB or SC synthetic rubber over which is woven a jacket of cotton or other suitable material and steel wire to impart strength and rigidity to the hose. The jacket is then coated with a heavy coat of lacquer or any other suitable flexible material.

The hose shall withstand the effects of fuel and lubricating oil. It shall operate satisfactorily at cold temperatures down to

−40 F. The hose is to assemble satisfactorily with fittings and couplings.

Sampling—*Lot Size*—Unless otherwise specified, a lot shall consist of all hose of one size submitted for inspection and test at one time.

Sampling—Two 40-in. lengths shall be selected at random for Physical Tests 1, 2, and 3 of this specification.

Six assemblies shall be selected at random from each lot for Physical Tests 4, 5, and 6 of this specification.

Each and every assembly shall be subjected to Physical Test 7, Coupling Leakage Test, of this specification.

Construction—*Tube*—The tube shall be of nonblooming seamless construction.

Reinforcement—The reinforcement shall consist of a circular-woven cotton carcass with an interwoven wire spiral. It shall be securely bonded to the tube.

Cover—The cover shall consist of a coating of gasoline, oil, and water-resistant flexible material.

Dimensions and tolerances shall be in accordance with Table 5.

TABLE 5—*Hose Diameters and Tolerances, SAE R 34*

DIAMETERS, IN.		TOLERANCES, IN., PLUS OR MINUS	
Inside	Outside	Inside	Outside
5/32	23/64	0.016	0.010
3/16	3/8	0.016	0.010
1/4	7/16	0.016	0.010
5/16	17/32	0.016	0.016
3/8	19/32	0.016	0.016
1/2	23/32	0.023	0.023

Physical Tests—The preparation of test samples is to be in accordance with ASTM D 380.

	Reference Paragraph	*Requirement*
1. *Original*		
1—Tensile, psi, minimum	111a	1000
2—Elongation	111a	200
2. *Oil Immersion* (70/212)	111b	
Per cent volume change		−5 to +100
3. *Cold Flexibility*	111c	
Original		−40 F
After oil immersion (70/212)		−40 F
4. *Burst*	111d	

The hose shall not burst, leak, or show signs of failure at a pressure lower than specified in Table 6.

5. *Vibration Test* 111e

This test is primarily a test of fittings and is to be run on coupled assemblies only.

6. *Tensile Test of Assemblies*—The end fittings of the assembly shall be clamped in the jaws of a tensile machine so that a straight pull may be applied. The jaws of the test machines shall separate at a speed of not greater than 12 in. per min. The minimum load required to pull off the end fittings or rupture the hose shall be 100 lb for 1/4 in. and under; 150 lb for 5/16 in. and over.

TABLE 6—*Proof-Pressure and Burst Tests for SAE R 34*

SIZE, IN.	PROOF PRESSURE, LB	BURST, LB
5/32	700	1400
3/16	600	1200
1/4	500	1000
5/16	500	1000
3/8	450	900
1/2	425	850

7. *Coupling Leakage Test*—Coupled sections shall withstand the proof pressure as specified in Table 6 for a minimum of 5 to 7 min without showing signs of leakage or failure.

8. *Corrosion Test*—The assembly shall be tested in accordance with ASTM B 117 for 48 hr. There shall be no evidence of corrosion or other deterioration at the expiration of this test.

Physical Test Procedures—*Tensile, Elongation*—ASTM D 380, Sections 8, 9, 10, 11.

Oil-Immersion Test—Specimens of the tube 2 in. long and of width equal to the circumference shall be immersed in ASTM Test Oil No. 3 (aniline point 159 ± 2 F) for 70 hr at 212 F in accordance with ASTM D 471, Section 8a.

Cold Flexibility Test—The cold flexibility test shall be made on an 18-in. length of the hose or an assembly. This test is to be made before and after filling the hose with ASTM Test Oil No. 3 (viscosity 150 ± 10 sec at 100 F; aniline point 159 ± 2 F) and heating in aging oven at 212 F for 70 hr. The hose shall be emptied and allowed to cool to room temperature before exposing to low temperature.

The hose shall be exposed for 5 hr to a temperature of −40 F in dry air. It shall then be bent over a mandrel having a diameter equal to ten times the outside diameter of the hose without cracking the tube or lacquer coating.

Burst Test—This test shall be performed on a straight length in accordance with ASTM D 380, Sections 15, 16, and 17 except that the length tested shall contain at least 8 in. of free length.

Vibration Test—Two coupled assemblies shall be placed in a vibration-test machine and subjected to the following test for a minimum of 100 hr without leakage or failure:

Inside diameter: 3/8 in. and under only
Length of sample: 8 in. minimum
Frequency of vibration: 1100 cpm ± 10 cycles
Total amplitude: 15/16 in.
Arrangement: 1½ in. offset at 90 deg to direction of stroke
Initial slack: 3/16 in.

During the tests ASTM Test Oil No. 1 or No. 3 at 250 F and 45 psi pressure shall be circulated through the hose. Continuous visible leakage shall be considered as a failure.

Automotive Brake Hoses (SAE R 40) SAE Standard

Report of Motorcoach and Motor Truck Division approved January 1942 and last revised by Nonmetallic Materials Technical Committee September 1949.

[*The specifications in this Standard originated in the ASTM–SAE Technical Committee on Automotive Rubber (other than tires). They represent the correlation of the best information available from research investigation and production experience on the minimum constructional and performance characteristics essential for new brake-hose assemblies used as original or replacement equipment. They also represent the minimum quality recognized by car manufacturers and hose suppliers as essential for satisfactory and safe operation by the hose itself and other coacting parts of the braking system. This Standard includes hoses for hydraulic, air, and vacuum brakes.*]

Hydraulic-Brake Hose (SAE R 41) Assembly Specification for ⅛-In. Hose

Scope—This specification covers a grade of hose fabricated from braid and natural rubber or from braid and synthetic rubber, assembled with steel end fittings for use on automotive hydraulic-brake equipment as flexible connections.

Manufacture—This hose shall consist of a rubber inner tube, two braids of cotton cord imbedded in and bonded to the rubber, and a rubber outer cover. The cover must be a black stock, free from sulfur bloom, which will not crack when subjected to long periods of weather aging. The inner tube of this hose must be a nonblooming stock which will effectively resist deterioration by brake fluids approved by the original vehicle manufacturers.

End Connections—Exposed steel end connections of the hose assembly shall be protected from rust or corrosion by copper, zinc, or nickel plating.

Hose Identification—Each manufacturer of hose shall identify his product by one or more colored cords woven into the braid.

(Note—The approved cord color designation for each brake-hose manufacturer shall be assigned by the Rubber Manufacturers Association, Inc., 444 Madison Avenue, New York City 22, N. Y.)

Each hose assembly must bear a distinctive designation prominently and permanently indicating the name or trade mark of the hose-assembly manufacturer.

Thirteen sample hose assemblies from each lot are required to run a complete test in accordance with this specification. In the interest of safety any assemblies remaining intact after these tests must be destroyed by cutting through at the center of the length.

Retests and Rejections—In the event of the failure of one sample of the thirteen selected at random from a lot to meet any of the following requirements, additional samples, as shown under Retest in Table 1 shall be submitted to the same test and the failure of any one of these shall be cause for rejection of the entire lot.

The temperature of the testing room shall be between 70 and 90 F (21 and 32 C). The samples to be tested shall be stabilized at room temperature previous to testing.

(Note—The above does not apply to the samples for the cold test.)

TABLE 1—*Samples Required for Test*[a], *SAE R 41*

	ORIGINAL TEST	RETEST
Expansion Followed by Burst Test	4	8
Whip Test	4	8
Tensile Test	4	8
Cold Test	1	2

[a] This specification does not show any items relating to the tensile strength, elongation, and other physical characteristics of the rubber compounds and materials composing the tube, cover, and cotton cord. The preparation of suitable test specimens for tensile strength and stretch from rubber hose of the diameter herein specified is impractical; furthermore, separate test slabs prepared from rubber compounds representing tube and cover compounds are not considered suitable.

Test Requirements—The assemblies for test shall be new and unused and shall be at least seven days old.

All tests must be made in accordance with the latest ASTM D 571, Methods of Testing Automotive Hydraulic Brake Hose.

Constriction—The constriction of the hose assemblies shall be measured with a gage plug whose "A" dimensions shall be 0.085 in. in diameter. The time required for the gage plug to drop of its own weight a distance of 3 in. into the hose assembly shall not exceed 5 sec.

Expansion—The maximum expansion of any of the hose assemblies so tested shall not exceed the values shown by the chart in Fig. 1.

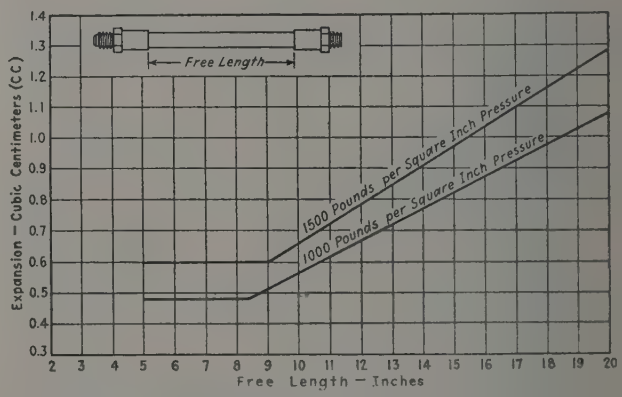


FIG. 1—MAXIMUM EXPANSION OF ⅛-IN. BRAKE HOSE, SAE R 41

Bursting Strength—When tested under hydraulic pressure, each sample of hose shall withstand a pressure of 3000 psi for one minute, followed by a 4000-psi pressure for one minute. The pressure shall then be increased at a rate of 25,000 (plus or minus 10,000) psi per min until burst occurs. The minimum bursting strength for any sample shall be 5000 psi.

Whip Test—The minimum life of any one of the sample hose assemblies with free lengths ranging from 8 to 24 in. run continuously on the flexing machine shall be 35 hr.

Tensile Test—The hose assembly is fixed in the testing machine and pulled at a speed of approximately one in. per min. All hose

assemblies so tested shall withstand a minimum pull of 325 lb without the end fittings pulling off or rupture of the hose.

Cold Test—The hose assembly shall be conditioned in a cold box in straight position at −40 F for 72 hr. After conditioning and without removal from the cold box, the hose shall be bent around a mandrel having a diameter of 3 in. The hose shall not crack or break.

Salt-Spray Test—The hose assembly end connections shall withstand 24-hr exposure to salt spray when tested in accordance with ASTM B 117.

100% Pressure Test—Before shipment by the vendor, every complete hose assembly shall be given a pressure test, using air or water as the pressure medium. The test pressure shall be 1500 to 1800 psi when water is used and shall be 1400 to 1700 psi when air is used. Special care should be taken in case air is used, as under the pressure specified, air is explosive if a failure should occur in the hose or hose assembly. The pressure shall be held for not less than 10 nor more than 25 sec. Hose assemblies showing leaks under this test shall be rejected and destroyed.

Air-Brake Hose (SAE R 42)

Scope—This specification covers two conventional types of air hose intended for use as flexible connections on automotive air-brake equipment. The hose may be either as fabricated for use with detachable end fittings or as assembled with metal end fittings. The types of hose are as follows:

Type A—Hose having a tube and friction of oil-resisting rubber and a cover of oil-resisting compound utilizing polymerized chloroprene as the basic material.

Type B—Hose having a tube and friction of crude or non oil-resisting rubber and a cover of oil-resisting compound utilizing polymerized chloroprene as the basic material.

Manufacture—The construction of hose for this service embodies a smooth-bore tube of flexible material, reinforced with cotton cord or duck plies, or a combination of both, together with an abrasive oil and age-resistant cover. The hose shall be so manufactured as to comply with the test requirements set forth in this Standard.

Hose Identification—The name or trade mark shall appear on the outer cover of the hose at intervals not greater than 36 in. apart. The hose shall be continuously branded with a color identifying the type of hose. Type A shall be identified by red branding, and Type B hose shall be identified by white color branding.

Retests and Rejections—Any hose which fails in one or more tests may be resampled and retested for which purpose two additional samples shall be selected from the hose for the test that failed to meet the requirements. Failure of either of the retested samples shall be cause for final rejection.

Sizes—The hose shall conform to the dimension requirements given in Table 2.

TABLE 2—*Air-Brake Hose Diameters, SAE R 42*

	HOSE SIZE						
Inside diameter, in., ±1/64	1/4	5/16	3/8[a]	7/16[a]	1/2	5/8	5/8 spec
Outside diameter, in., ±1/32	5/8	11/16	3/4	13/16	7/8	1 1/8	1 3/8 max

[a] These sizes are standard and should be used when possible.

Samples for Tests—A representative sample of hose approximately 6 ft in length shall be selected from each lot to be tested. If a single length of 6 ft is not available, several sections, each of sufficient length to provide the required test specimens, may be taken.

Test Requirements—All measurements and tests necessary for determining the conformity of the hose with these specifications shall be made in accordance with ASTM D 622, Methods of Testing Automotive Air Brake and Vacuum Brake Hose.

To qualify hose under this specification, all of the requirements shown under qualification tests and inspection tests must be met. Production shipments or lots of the qualified hose shall meet the requirements shown under inspection tests, but the user may in addition, if he so desires, test hose from any or all such production shipments or lots to the requirements under the qualification tests.

Qualification Tests—*Aging Test*—The hose shall show no cracks, charring, or disintegration externally or internally when straightened after being bent over a form having the radius given in Table 3 after a period of 70 hr in an oven at 100 ± 1 C (212 ± 1.8 F).

TABLE 3—*Air-Brake Hose Aging Test, SAE R 42*

	HOSE SIZE, INSIDE DIAMETER, IN.						
	1/4	5/16	3/8	7/16	1/2	5/8	5/8 spec
Length of specimen, in...	9	10	10	11	11	12	14
Radius of form.....	1 1/2	1 3/4	1 3/4	2	2	2 1/4	2 1/2

Cold Test—After being subjected to this test, the hose shall show no signs of cracking or breaking.

Inspection Tests—The hose shall conform to the following test requirements:

Air-Pressure Test—The hose and couplings shall show no leakage under air pressure of 200 psi for 5 min.

Bursting Test—The minimum bursting strength of the hose shall be 900 psi when tested with hydrostatic pressure.

Tensile Test—The hose assembly complete with couplings shall withstand a minimum pull of 325 lb without separation from the couplings or rupture of the hose structure.

Swell Test of Tube and Cover in Type A Hose and Cover in Type B Hose—A specimen prepared from the inner tube and from the cover of the hose shall show a volume increase when measured within 5 min after removal from ASTM precipitation naphtha in which it has been immersed for 24 hr at room temperature of not more than 35% for the inner tube and 50% for the cover.

Vacuum-Brake Hose (SAE R 43)

Scope—This specification covers vacuum hose intended for use in the braking systems of single vehicles or as connecting or transmission lines in combination of vehicles or systems thereof.

Manufacture—The construction of hose for this service embodies a smooth-bore tube of flexible material, reinforced with cord or duck plies, or a combination of both, together with an abrasive-, weather-, and sunlight-resistant cover. The hose shall be so manufactured as to comply with the test requirements set forth in this Standard.

Hose Identification—The name or trademark and date code

shall appear on the outer cover of the hose at intervals not greater than 36 in. apart.[1]

Retests and Rejections—Any hose which fails in one or more tests shall be resampled and retested, for which purpose two additional samples shall be selected from the lot for the test that failed to meet the requirements. Failure of either of the retested samples shall be cause for final rejection of the lot.

Sizes—The hose shall conform to the dimensional requirements given in Table 4.

TABLE 4—*Vacuum-Brake Hose Diameters, SAE R 43*

	HOSE SIZE					
Inside diameter, in.	¼	⅜	½	⅝	¾	1
Tolerance plus	0.008	0.008	0.008	0.008	0.008	0.010
Tolerance minus	0.020	0.020	0.020	0.020	0.020	0.022
Outside diameter, in.	9/16	13/16	15/16	1 1/16	1 3/16	1 15/32
Tolerance plus	1/32	1/32	1/32	1/32	1/32	1/32
Tolerance minus	1/32	1/32	1/32	1/32	1/32	1/32

Samples for Test—A representative sample of hose approximately 15 ft in length shall be selected from each lot to be tested. If a single length of 15 ft is not available, several sections, each of sufficient length to provide the required test specimens, may be taken. The samples shall be not less than 7 days nor more than 120 days old.

Test Requirements—All measurements and tests necessary for determining the conformity of the hose with these specifications shall be made in accordance with ASTM D 622, Methods of Testing Automotive Air Brake and Vacuum Brake Hose.

To qualify hose under this specification, all of the requirements shown under qualification tests and inspection tests must be met. Production shipments or lots of the qualified hose shall meet the requirements shown under inspection tests, but the user may in addition, if he so desires, test hose from any or all such production shipments or lots to the requirements under qualification tests.

Qualification Tests—*Aging Test*—The hose shall show no cracks, charring, or disintegration externally or internally when straightened after being bent over a form having the radius given in Table 5, after a period of 70 hr in an air oven at 100 ± 1 C (212 ± 1.8 F).

Cold Test—After being subjected to this test, the hose shall show no signs of cracking or breaking.

Inspection Tests—*Bursting Test*—The hose shall not burst, leak, or show signs of failure at a hydrostatic pressure lower than specified in Table 5.

Vacuum Test—The collapse of the outside diameter of the hose under internal vacuum of 29 in. of mercury for 5 min shall not exceed 1/16 in.

[1] The manufacturers of vacuum-brake hose shall obtain the date code from the Rubber Manufacturers Association, 444 Madison Avenue, New York 22, New York.

TABLE 5—*Vacuum-Brake Hose Test Requirements, SAE R 43*

HOSE	TESTS						
	Aging		Bend		Deformation	Burst	Swell
ID, in.	Specimen length, in.	Radius of form, in.	Specimen length, in.	Maximum collapse of OD, in.	Collapsed ID (dimen D), in.	Psi	Diameter of ball, in.
¼	9	1½	8	3/32	1/16	1200	3/16
⅜	10	1¾	12	5/32	3/32	1200	5/16
½	11	2	16	7/32	⅛	1000	13/32
⅝	12	2¼	22	7/32	5/32	1000	17/32
¾	14	2½	28	7/32	3/16	800	⅝
1	16	3¼	36	9/32	¼	800	⅞

Bend Test—The collapse of the outside diameter of the hose at the middle point of the test length when bent until the ends touch shall not exceed the values given in Table 5.

Deformation Test—A specimen 1 in. long shall be compressed five times to a collapsed inside diameter (dimen D) in Table 5. The load required in the first compression shall be less than 70 lb, and in the fifth compression shall be greater than 40 lb. After the test, the specimen shall immediately return to at least 90% of the original outside diameter.

Swell Test—The hose shall be filled with di-isobutylene and held 48 hr at room temperature, after which time the di-isobutylene shall be removed and immediately a steel ball of the diameter given in Table 5 shall pass through the hose freely. The sample shall then show no leakage in vacuum test under 26 in. of mercury for 10 min, after which there shall be no separation of the inner tube from the fabric reinforcement of the hose

Adhesion Test—The minimum load required to separate the tube from plies, the plies, and the cover from the plies shall be 10 lb. This test is to be made only on original, not aged specimens.

Cover Tensile—The cover stock shall have a minimum tensile strength of 1200 psi.

Cover Elongation—The cover stock shall have a minimum elongation at break of 200% (2 in. to 6 in.).

Color Assignments to Brake-Hose Manufacturers

As of October 14, 1948 the Rubber Manufacturers Association, 444 Madison Ave., New York City 22, has assigned brake-hose identification colors to the hose manufacturers as follows:

Blue	Raybestos-Manhattan, Inc.
Red	United States Rubber Co.
Green	Goodyear Tire & Rubber Co.
Black	Inland Div., General Motors Corp.
Brown	Republic Rubber Co.
Yellow	B. F. Goodrich Co.
Red and Black	Dominion Rubber Co., Ltd.

Windshield-Wiper Hose (SAE R 50) SAE Standard

Report of Nonmetallic Materials Division approved January 1945.

[*This Standard was formulated by SAE—ASTM Technical Committee on Automotive Rubber.*]

Construction—The hose shall consist of an inner tube of flexible material, reinforced with one or more plies of wrapped fabric or braided cord, or a combination of both, and a cover of flexible material. The tube and cover shall be smooth and uniform in thickness in accordance with good manufacturing practice.

The hose shall be so manufactured as to comply with the test requirements set forth below. Where not specifically designated, the materials and construction shall be suitable for the purpose intended.

Sizes and Tolerances—The inside diameter shall be $\frac{5}{32}$, $\frac{7}{32}$ in.; outside diameter shall be $1\frac{1}{32}$, $1\frac{3}{32}$ in. The inside diameter shall be subject to a tolerance of plus or minus $\frac{1}{64}$ in. and the outside diameter to a tolerance of plus $\frac{3}{64}$ in., minus $\frac{1}{64}$ in.

Length—Unless otherwise specified, the hose shall be furnished in coils of nominal 50-ft lengths or in "reel lengths" of nominal 500 ft. The reels may consist of a maximum of four lengths but the minimum length shall be 25 ft.

When "cut lengths" are specified on the contract or order, the length shall not vary by more than plus $\frac{1}{16}$ in., minus $\frac{1}{32}$ in. on lengths up to 3 in.; plus or minus $\frac{1}{16}$ in. on lengths 3 in. to 18 in.; plus or minus $\frac{1}{4}$ in. on lengths 18 in. to 100 in.; and plus or minus 1% on lengths over 100 in.

Methods of Test—Measurements and tests shall be made in accordance with ASTM D 380, Methods of Test of Hose, unless otherwise specified in this Standard.

Test Requirements—*Burst*—The hose shall not burst at a pressure less than 250 psi.

Bend Test—No breaking of reinforcement or other components shall occur when the hose is bent at a 90-deg angle while installed on the proper size tubing ($\frac{3}{16}$ in. for the $\frac{5}{32}$-in. size and $\frac{1}{4}$ in. for the $\frac{7}{32}$-in. size).

Vacuum Collapse—The hose shall be subjected to a vacuum of 24 in. of mercury while being curved to a radius equal to five times the maximum outside diameter of the hose. After 5 min, the outside diameter shall not have been reduced by more than 30%. During this test, the inner tube shall not collapse nor pull away from the reinforcement. Tube collapse may be determined by sectioning the hose lengthwise and examining.

Cold Flexibility—Samples of hose shall be subjected to a temperature of minus 20 F for a period of 5 hr after which the hose shall be flexed in the cold chamber through 180 deg from the center line in each direction to a diameter 10 times the maximum outside diameter of the hose at each extreme of cycle for five cycles. The rate of cycling shall be approximately one cycle in 4 sec. The hose shall not fracture nor show any cracks, checks, or breaks in the tube or cover.

Tension Test—The ends of a sample of hose shall be fastened in the jaws of a testing machine. The jaws shall then be separated at the rate of 1 in. per min until rupture of the hose occurs. Failure shall not occur at a tension of less than 60 lb for the $\frac{5}{32}$-in. size and 80 lb for the $\frac{7}{32}$-in. size.

Aging Test—After being subjected to dry air aging in accordance with ASTM D 573 for 70 hr at 158 ± 2 F, the hose shall meet the requirements for vacuum collapse and cold flexibility outlined above.

Sampling—From each lot of 25,000 ft or less of hose, representative samples shall be taken to determine conformance with this specification.

Samples of suitable length for conducting the tests shall be used but shall not exceed 12 in. except in the case of the burst test which shall be conducted on a sample not exceeding 18 in. A separate sample shall be used for each test.

For methods of inspection, retest, and rejection, refer to ASTM D 380.

Natural-Rubber Cups for Hydraulic Actuating Cylinders (SAE R 60) SAE Standard

Report of Nonmetallic Materials Technical Committee approved January 1946. This Standard conforms with Tentative Specifications for Natural Rubber Cups for Use in Hydraulic Actuating Cylinders, ASTM D 818 — 45T.

[*This SAE Standard for natural-rubber cups was formulated by Section IX of SAE-ASTM Technical Committee on Automotive Rubber.*]

1. **Scope**—These specifications cover molded cups compounded from natural rubber for use in hydraulic actuating cylinders employing hydraulic-brake fluid of nonmineral oil type.

(Note—These specifications do not include requirements relating to chemical composition, tensile strength, and elongation of the rubber compounds and materials composing the cup. The preparation of suitable specimens for tensile strength and elongation tests from a cup herein specified is impractical; furthermore, separate test slabs prepared from rubber compounds representing the cups are not considered suitable.)

TEST REQUIREMENTS

2. **Resistance to Fluids at Elevated Temperatures**—After being subjected to the test for resistance to fluids at elevated temperatures as prescribed in Sections 11 to 14, the cups shall

conform to the following requirements as to changes in dimensions and durometer hardness:

Change in:

volume ..... 0 to +20%

outside diameter, lip ..... 0 to +5.75% (0 to +0.075 in.)

base .... 0 to +5.75% (0 to +0.075 in.)

durometer hardness ..... −10 to + 5 points

3. **Effect of Fluid Pressure at Elevated Temperature (Heat-Pressure Test)**—After being subjected to the heat-pressure test prescribed in Sections 15 to 18, the cups shall conform to the following requirements as to changes in dimensions and durometer hardness:

Measurements after 30 min:

Change in:

outside diameter, lip −2 to +2% (−0.025 to +0.025 in.)

base +3% maximum (+0.040 in. maximum).

durometer hardness ..... −5 to +0 points

Measurements after 48 hr:

Change in:

outside diameter, lip −3 to +2% (−0.040 to +0.025 in.)

base +3% max (+0.040 in. max)

durometer hardness ..... −5 to +0 points

4. **Stroking Test**

(a) There shall be no leakage of fluid past the primary or secondary cups during the stroking test.

(b) After the stroking test, specimens shall be examined for wear and general condition which may affect their life and performance.

(c) The change in durometer hardness after the stroking test shall be within the limits of −7 to +5 points from the original reading.

5. **Low-Temperature Test**

(a) After being held for 120 hr at −40 to −45 F, the durometer hardness of the specimen shall not increase more than 25 points over the reading taken at room temperature.

(b) After the bend test, made while the specimen is held at a temperature of −40 to −45 F following an exposure at this temperature for 120 hr, the cup shall return to its approximate original shape within 1 min.

(c) No leakage of fluid shall occur past the primary, secondary, or wheel-cylinder cups during the low-temperature leakage test.

6. **Aging**

(a) The change in durometer hardness shall be within the limits of 0 to +5 points over the reading taken before aging.

(b) After the aging test, the specimens shall be examined for general condition and defects which may affect their life and performance.

7. **Manufacture**—Cups shall be free from blisters, pin holes, cracks, protuberances, embedded foreign matter, or other physical defects which can be detected by thorough inspection, and shall conform to the dimensions specified on the drawings. The sealing lip shall be sharp and free from any irregularities.

8. **Marking**—The identification mark of the manufacturer, cup size, and other details as specified on the drawings shall be molded into each cup.

METHODS OF TESTING

9. **Sampling**

(a) A quantity of 5000 cups of one size shall represent the minimum lot on which complete tests shall be conducted. The frequency and type of tests used to control production shall be agreed upon by the manufacturer and the purchaser.

(b) Specimens for heat-pressure and resistance-to-fluid tests shall be 1¼-in. diameter wheel-cylinder cups, and for stroking tests shall be 1⅛-in. diameter primary and secondary cups. When conditions do not permit the use of these sizes, tests shall be made on cups of available size, in which case the percentage limits of the specifications shall apply.

(c) Cups used for purpose of tests shall not be more than six months old from the date of manufacture.

10. **Test Fluids**—The fluid used in the tests shall be one of the standard non mineral-oil brake fluids as follows: Chrysler ISO Brake; Delco No. 9; Ford M-3833A; Wagner No. 21; and fluids approved in Army Ordnance Specification 2-111, latest issue.

RESISTANCE TO FLUIDS AT ELEVATED TEMPERATURE

11. **Apparatus**

(a) *Micrometer*—Micrometer calipers or other suitable apparatus to measure the lip and base diameters of the cup accurately in thousandths of an inch.

(b) *Containers*—Tightly sealed containers of ½-pt capacity.

(c) *Oven*—Any well designed uniformly heated standard dry-air oven conforming to the requirements prescribed in Section 4 of the Standard Method of Test for Accelerated Aging of Vulcanized Rubber by the Oven Method (ASTM D 573) may be used. The oven shall be provided with proper temperature controls to maintain a standard test temperature of 158 ± 2 F. Satisfactory circulation of air shall be secured by means of a fan.

12. **Test Specimens**—Two cups shall be selected for use as test specimens. See Section 9(b).

13. **Procedure**

(a) The specimens shall be wiped with an alcohol-saturated, lint-free cloth to remove dirt and packing debris.

(b) The volume of each specimen shall be determined in accordance with Section 9a, Tentative Methods of Test for Changes in Properties of Rubber and Rubber-Like Materials in Liquids (ASTM D 471), except that a Jolly balance may be used.

(c) The diameters of the lip and base of the specimen shall be measured to the nearest thousandth of an inch, taking the average of two readings at right angles. Care shall be taken when measuring the base diameter that the measurement is taken within 0.015 in. from the back and parallel to the base of the specimen.

(d) The durometer hardness of the specimen shall be determined in accordance with Section 28. Two specimens shall be put in a ½-pt container containing 75 ml of the specified test fluid, and the container shall be sealed to prevent loss of vapor during the test. The container shall be placed in the oven at 158 ± 2 F for 120 hr. At the end of the heating period the container shall be taken from the oven and the test specimens removed immediately and wiped dry with an alcohol-saturated lint-free cloth.

(e) The test specimens shall be cooled for 30 min on a wooden table top. The final volume, dimensions, and durometer hardness of each specimen shall then be determined as described in (b) to (d) above.

(*Continued on next page.*)

14. Calculations and Report

(a) *Volume Change*—The change in volume shall be reported, calculated as follows:

Increase in volume, percent, equals

$$\frac{(W_3 - W_4) - (W_1 - W_2) \times 100}{W_1 - W_2}$$

where W_1 = initial weight in air
W_2 = initial weight in water
W_3 = weight in air after immersion in the test fluid
W_4 = weight in water after immersion in the test fluid

(b) *Dimensional Change*—The original measurements shall be subtracted from the measurements taken after the test and the difference reported in thousandths of an inch and as a percentage. Any observable changes in the condition of the specimens shall also be reported.

(c) *Durometer Hardness*—The difference between the original durometer hardness reading and the reading after the test shall be reported.

HEAT-PRESSURE TEST

15. Apparatus

(a) *Oven*—Any well designed uniformly heated standard dry-air oven of sufficient size to hold the heat-pressure device may be used. The oven shall be provided with proper temperature controls to maintain a standard test temperature of 158 ± 2 F. Satisfactory circulation of air shall be secured by means of a fan. The heat-pressure device shall be centrally located in the oven and supported above the bottom of the oven by suitable supports. A suitable oven is described in Section 4, ASTM D 573.

(b) *Heat Pressure Device*—Suitable means shall be provided to maintain a pressure of 500 psi in cylinders used in the heat-pressure test. The apparatus shown in Figs. 1 and 2 has been found satisfactory.

16. Test Specimens—Two wheel-cylinder cups shall be selected for use as test specimens.

17. Procedure

(a) The specimens shall be wiped with an alcohol-saturated, lint-free cloth to remove dirt and packing debris.

(b) The diameters of the lip and base of the specimen shall be measured to the nearest thousandth of an inch, taking the average of two readings, at right angles. Care shall be taken when measuring the base diameter that the measurement is taken within 0.015 in. from the back and parallel to the base of the specimen.

(c) The durometer hardness of the specimens shall be determined in accordance with Section 28.

(d) The specimens shall be installed in a wheel cylinder and connected to a master cylinder with weighted arm (Figs. 1 and 2 are typical arrangements). The system shall be filled with the specified test fluid and all air expelled by bleeding. The weight on the master cylinder arm shall be adjusted to maintain a pressure of 500 ± 50 psi in the system. The test shall be continued for 120 hr at 158 ± 2 F. At the termination of the heating period, the specimens shall be removed from the cylinder and wiped clean with an alcohol-saturated, lint-free cloth.

(e) The specimens shall be cooled for 30 min on a wooden table top, after which measurements of the dimensions and durometer hardness shall be taken as prescribed in (b) and (c) above.

(f) The specimens shall then be rested for 48 hr on a wooden table top at room temperature after which the measurements of the dimensions and durometer hardness shall be repeated.

18. Calculations and Report—The changes in dimensions and durometer hardness shall be calculated and reported as described in Section 14 (b) and (c).

STROKING TEST

19. Apparatus

(a) *Stroking Machine*—The stroking machine shall consist of a suitable mechanical means for actuating the master cylinder containing the test specimens, which shall be operated at 1000

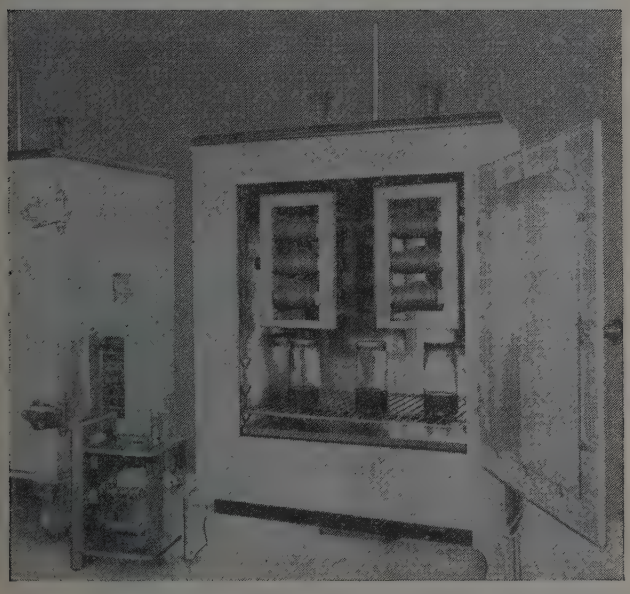


FIG. 1—OVEN SHOWING FIXTURES FOR HEAT-PRESSURE TEST AND CONTAINERS FOR FLUID-RESISTANCE TEST

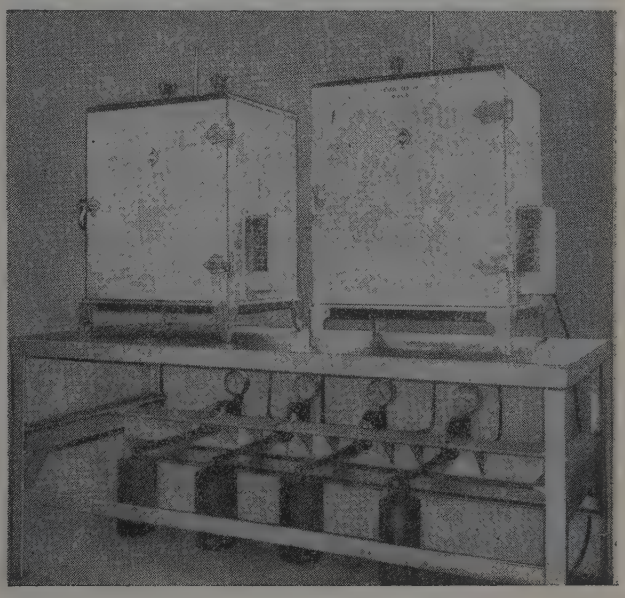


FIG. 2—OVEN SHOWING WEIGHTED MASTER CYLINDER FOR APPLYING PRESSURE IN HEAT-PRESSURE TEST

± 100 strokes per hr with a total piston movement of $1\frac{7}{16}$ in. The initial movement of $\frac{5}{8}$ in. to $1\frac{1}{16}$ in. shall be at a pressure of 40 to 50 psi to permit the primary cup to pass over the compensating port hole, and the balance of the stroke shall be at a test pressure of 500 ± 50 psi, held constant by an adjustable relief valve. If master cylinder sizes other than those recommended are used, there shall be a minimum total movement of master-cylinder piston of $1\frac{1}{16}$ in. with a minimum stroke of $\frac{1}{2}$ in. after the primary cup passes over the compensating port hole. The master cylinder shall be located in a uniformly heated dry-air oven maintained at the standard test temperature of 158 ±2 F. The equipment shown in Figs. 3 and 4 has been found satisfactory.

(b) *Alternative Stroking Machine*—One hydraulic brake system master cylinder $1\frac{1}{8}$ in. in diameter, four brake assemblies having $1\frac{1}{4}$-in. diameter wheel cylinders, brake drums, a pressure gage satisfactory for operation at 500 ± 50 psi, and approximately 15 ft of $\frac{1}{4}$-in. outside diameter copper or steel tubing shall be used in assembling the apparatus. The master cylinder shall be enclosed in a heated air bath maintained at a temperature of 158 ± 2 F. Mechanical application of pressure to the master-cylinder push rod shall be employed to simulate operation on the vehicle as closely as possible. At the start of the test, the brake shoes shall be adjusted concentric with the brake assembly axis to provide a diametral clearance of 0.080 in. between the shoes and drums (0.040-in. clearance on each side). The equipment shown in Fig. 5 has been found satisfactory.

[1] A master cylinder shall not be used for more than one test.

20. **Test Specimens**—One primary cup and one secondary cup shall be selected for use as test specimens. See Section 9(b).

21. **Procedure**

(a) The specimens shall be wiped with an alcohol-saturated, lint-free cloth to remove dirt and packing debris and then examined and the general condition recorded.

(b) The durometer hardness of the specimens shall be determined in accordance with Section 28.

(c) The specimens and master-cylinder internal parts shall be dipped in the specified test fluid and the cylinder walls coated with the specified test fluid before assembly.

(d) The system shall be filled with the specified test fluid and all air expelled by bleeding. The master-cylinder[1] assembly shall be installed in an oven and operated for 150,000 strokes at a rate of 1000 ± 100 strokes per hr and at a temperature 158 ± 2 F. The equipment shown in Figs. 3, 4, and 5 has been found satisfactory.

(e) After this test, the specimens shall be removed from the cylinders, wiped with an alcohol-saturated, lint-free cloth and cooled for 30 min on a wooden table top. The durometer hardness shall then be determined in accordance with Section 28 and a thorough inspection made of the cup condition.

LOW-TEMPERATURE TEST

22. **Apparatus**—*Cold Chamber*—The chamber in which the test specimens are exposed to the low temperature shall be of sufficient size to contain the leakage apparatus loaded with

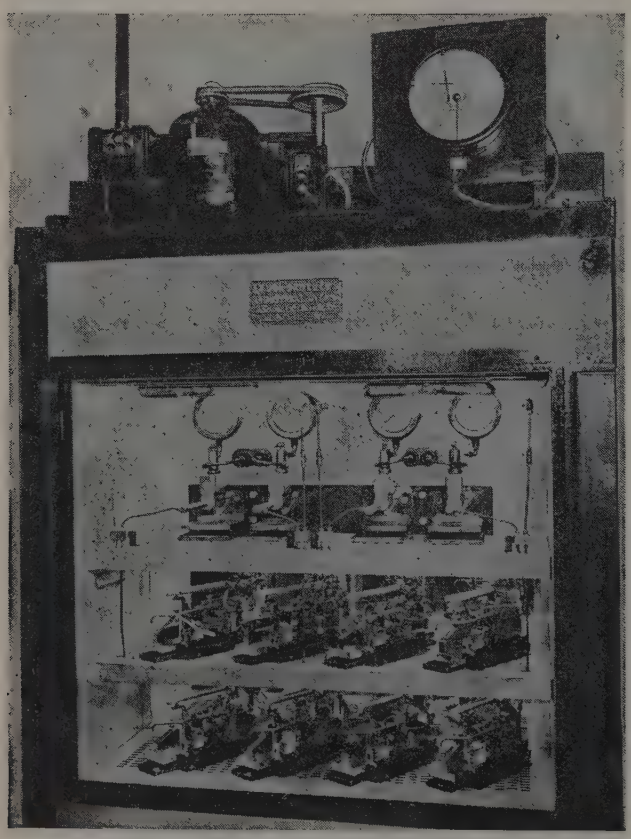


FIG. 3—STROKING-TEST APPARATUS

FIG. 4—ACTUATING MECHANISM FOR STROKING-TEST APPARATUS

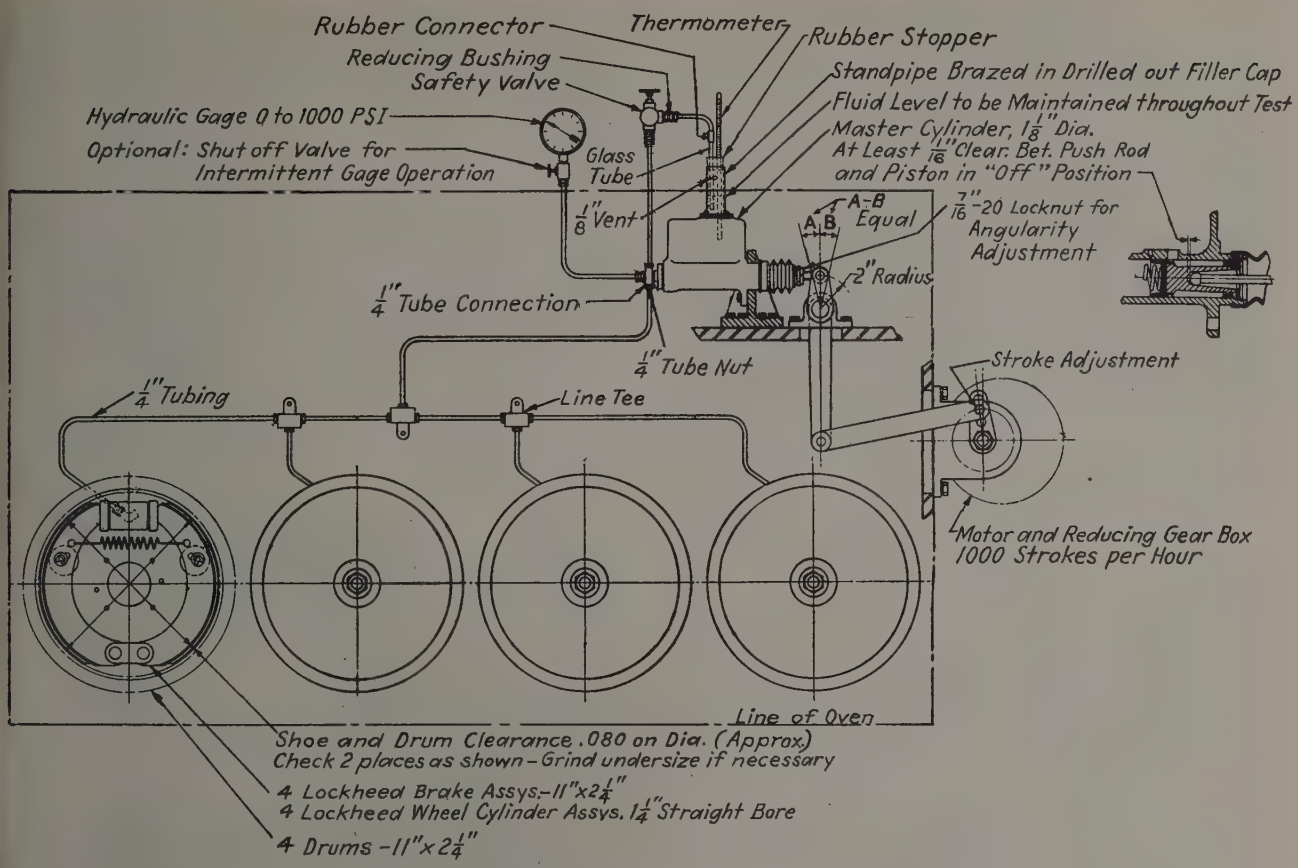

Rubber Connector
Thermometer
Rubber Stopper
Reducing Bushing
Safety Valve
Standpipe Brazed in Drilled out Filler Cap
Fluid Level to be Maintained throughout Test
Hydraulic Gage 0 to 1000 PSI
Optional: Shut off Valve for Intermittent Gage Operation
Glass Tube
Master Cylinder, 1 1/8" Dia.
At Least 1/16" Clear. Bet. Push Rod and Piston in "Off" Position
1/8" Vent
A-B Equal
7/16"-20 Locknut for Angularity Adjustment
2" Radius
1/4" Tube Connection
1/4" Tube Nut
Stroke Adjustment
1/4" Tubing
Line Tee
Motor and Reducing Gear Box 1000 Strokes per Hour
Line of Oven
Shoe and Drum Clearance .080 on Dia. (Approx.)
Check 2 places as shown - Grind undersize if necessary
4 Lockheed Brake Assys.-11"x2 1/4"
4 Lockheed Wheel Cylinder Assys. 1 1/4" Straight Bore
4 Drums -11"x2 1/4"

FIG. 5—ALTERNATIVE STROKING-TEST APPARATUS

specimens and so arranged as to permit the operator to check and operate the apparatus without removal from the chamber. It shall be capable of maintaining a uniform atmosphere of cold dry air within the specified temperature range of −40 to −45 F. The equipment shown in Fig. 6 has been found satisfactory.

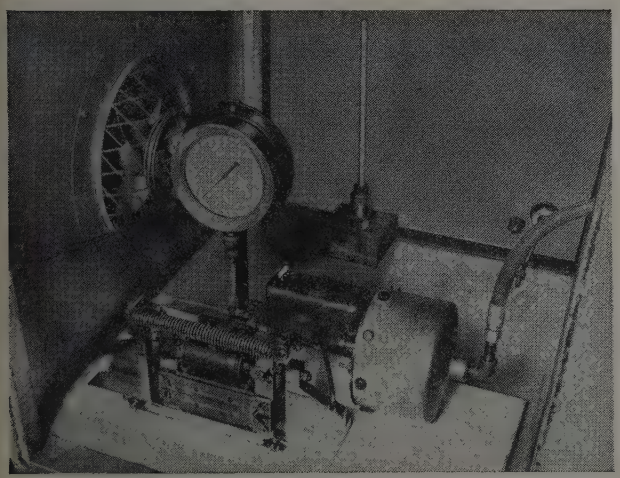


FIG. 6—LEAKAGE APPARATUS USED IN LOW-TEMPERATURE TEST

23. **Test Specimens**—Three wheel-cylinder cups, two primary cups, and two secondary master-cylinder cups shall be selected as test specimens.

24. **Procedure**

(a) The specimens shall be wiped with an alcohol-saturated, lint-free cloth to remove dirt and packing debris.

(b) *Hardness Test*

(1) The durometer hardness shall be determined in accordance with Section 28.

(2) One wheel-cylinder cup, one primary cup, and one secondary master-cylinder cup shall be placed in the cold box for 120 hr at −40 to −45 F. The durometer and the test jig shall also be subjected to the same temperature for the last ½ hr of the 120-hr period. While the apparatus is in the cold chamber and the specimen is at a temperature of −40 to −45 F, the durometer hardness shall be determined in accordance with Section 28.

(Note—It is necessary to store the durometer used in the cold test in a desiccator for a period of at least 1 hr before and 1 hr after use in the cold box to keep it free of moisture.)

(c) *Bend Test*—After an exposure for 120 hr at −40 to −45 F, the cups shall be bent between the thumb and finger through an angle of approximately 90 deg and released immediately. The cold cups shall be bent while in the chamber and shall be handled with gloves to prevent heating from the fingers.

(d) *Leakage Test*

(1) The apparatus shall consist of a master cylinder and a wheel cylinder so connected that their operation simulates the

brake system in actual service. The apparatus shown in Fig. 6 has been found satisfactory.

(2) The specimens shall be wiped clean with an alcohol-saturated, lint-free cloth and assembled in the system, which has previously been conditioned as prescribed in Section 21(c). The system shall then be filled with the specified test fluid and the air bled from the system.

(3) The complete system shall be enclosed in a cold chamber equipped with a glass door for observation and subjected to a temperature of −40 to −45 F for a period of 120 hr. During this period no leakage of fluid past the cups shall occur.

(4) The master-cylinder piston shall then be operated at an approximate rate of 1 stroke per min at a pressure of 500 psi. The piston shall return to the piston stop after each stroke. After 12 piston strokes, there shall be no evidence of fluid leakage past the cups.

(5) The operation described in (4) shall be repeated at a pressure of 1000 psi.

AGING TEST

25. **Test Specimens**—Two cups shall be selected as test specimens.

26. **Procedure**

(a) The specimens shall be wiped with an alcohol-saturated, lint-free cloth to remove dirt and packing debris.

(b) The original durometer hardness shall be determined in accordance with Section 28.

(c) The two best specimens shall be placed in a circulation air oven as prescribed in ASTM D 573 and held for 70 hr at 158 ± 2 F.

(d) At the termination of the heating period, the specimens shall be removed from the oven and allowed to cool for 30 min on a wooden table top to room temperature.

(e) The durometer hardness after aging shall be determined in accordance with Section 28 and the specimens visually inspected.

DUROMETER HARDNESS

27. **Apparatus**

(a) *Durometer*—A durometer, type A, which shall be calibrated as described in the Method of Test for Indentation of Rubber by Means of the Durometer (ASTM D 676).

(b) *Fixture*—Fixture for holding the durometer and anvil is as shown in Fig. 7.

(c) *Anvil*—Rubber anvil having a durometer hardness of 46 to 48 is as shown in Fig. 7.

28. **Procedure**—The durometer hardness of the specimen shall be determined using the apparatus as illustrated in Fig. 7. The anvil of the durometer when resting on the specimen shall be level with the indentor point contacting the specimen at the position shown in Fig. 7.

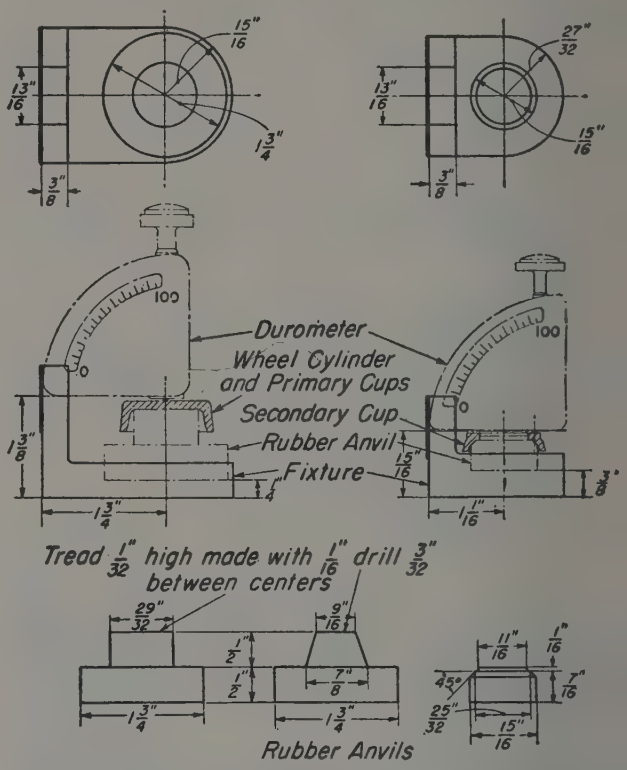


FIG. 7—APPARATUS FOR MEASURING DUROMETER HARDNESS

The durometer shall not be pressed against the specimen harder than is necessary to make contact between the rubber and the entire face of the durometer anvil. The immediate reading of the durometer hardness shall be used. The same operator shall make all hardness determinations for any one test.

(Note—Since small variations in the pressure of application of the durometer produce considerable variation in results, it is recommended that the above instructions be rigidly followed.)

Automotive Rubber Mats

SAE Standard

Report of Nonmetallic Materials Technical Committee approved January 1951.

[This Standard was prepared by the SAE—ASTM Technical Committee on Automotive Rubber.]

General Requirements

Sampling—A representative mat shall be selected from each lot to be tested.

Workmanship and Finish—The workmanship and finish shall be such as to provide a mat with a clean surface, cleanly trimmed edges, holes free from slugs, and otherwise neat in appearance.

Color—The color shall be designated by the consumer.

Packing, Marking, and Shipping—Details regarding packing, marking, and shipping are subject to individual arrangements between consumer and producer.

Retests and Rejections—Any lot of mats which fails in one or more tests shall be resampled and retested for which purpose two additional mats shall be selected from the lot that failed to meet the requirements. Failure of either of the retested samples to meet any of the specification requirements shall be cause for final rejection.

Physical Test Procedures

Conditioning—Sections of automotive mats or mat samples, which have been allowed to rest at least 16 hr after cure, are to be conditioned 6 hr at 158 F in accordance with Standard Method of Test for Accelerated Aging of Vulcanized Rubber by the Oven Method, (ASTM D 573) before any physical tests are performed.[1] At the termination of the conditioning interval, the sections shall be removed from the oven, placed on a flat surface, and allowed to rest 16 hr (minimum) at room temperature before determining physical properties.

Durometer Hardness—Hardness is to be measured with an instrument according to Method of Test for Indentation of Rubber by Means of a Durometer, ASTM D 676. Tests shall be made on not less than ¼-in. thickness to be made up by laying together smooth layers of the test samples.

[1] This conditioning period is optional and is to be arranged between producer and consumer.

Tensile Strength and Elongation—Tensile strength and elongation shall be determined in accordance with Standard Method of Tension Testing of Vulcanized Rubber, ASTM D 412, using die A, except that the average calculation shall be made on not less than three dumbbell specimens with the grain, and three across the grain, rather than the method specified in Section 9.

Note—Any test specimen which shows imperfect preparation shall be discarded and a new specimen prepared and tested.

Oven Aging—Tests shall be made in accordance with Standard Method of Test for Accelerated Aging of Rubber by Oven Method, ASTM D 573.

Bend Test—The bend test shall be performed on conditioned test specimens. The test specimen shall not crack when bent around a 1/16-in. rod.

Test Requirements—Test requirements are shown in Table 1.

TABLE 1—*Test Requirements*

Properties (After Conditioning 6 Hr at 158 F)				
Type	2	3	1	4
Durometer	70 ± 5	70 ± 5	70 ± 5	70 ± 5
Tensile strength, psi, min	600	400	400	900
Elongation, %, min	200	225	150	250
Bend test	no cracking			
Oven Aging (70 Hr at 158 F After Conditioning)				
Durometer, points increase, max	10	10	10	10
Tensile strength, % decrease, max	25	25	25	25
Elongation, % decrease, max	35	35	35	35
Elongation, %, min	150	175	115	175
Bend test	no cracking			

Hydraulic-Brake Fluid (SAE R 70) SAE Standard

Report of Nonmetallic Materials Technical Committee approved December 1946 and last revised January 1949.

Heavy-Duty Type (SAE R 71)

A—Type—These specifications cover brake fluids of the nonmineral oil type for use in the atmospheric range of approximately 140 to −60 F, in highway vehicles where the brake fluid is exposed to severe operating conditions.

B—Material—The materials used shall be such that the resulting compound will conform to the requirements of these specifications.

C—Detail Requirements—Hydraulic-brake fluids covered by these specifications shall be in accordance with Table 1, Table 2, and Sections C1, C2, C3, C4, C5, C6, and C7.

TABLE 1—*Required Tests for SAE R 71*

TESTS	TEST LIMITS
Viscosity (kinematic) at −40 F, max	2200 centistokes
Viscosity (kinematic) at 130 F, min	3.5 centistokes
Cold test (6 days at −40 F)	Shall begin to flow within 5 sec after the sample bottle is tilted from the vertical to horizontal position. No stratification or precipitation.
Freezing point (6 hr at −60 F)	Shall begin to flow within 5 sec after the sample bottle is tilted from the vertical to horizontal position.
Boiling point, F, min	300
Flash point, F, min	145
Water tolerance (3.5 cc of water at 140 and −40 F)	No stratification or precipitation.
Neutrality	pH 6.0 to 9.5
Neutrality (after corrosion test)	pH 6.0 to 9.5

C1—Corrosion—The fluid when tested under conditions outlined in Section D8 shall not cause corrosion exceeding the limits shown in Table 2. The fluid after test shall not show jelling or any substantial amount of sludge formation.

Discoloration or slight generalized pitting of the test strips shall not be cause for rejection of the fluid.

C2—Stability—The boiling point shall not be less than 295 F after the fluid has been held at 295 F for 6 hr in the presence of a rubber cup (Lockheed Manhattan FC-666-XO) and steel, aluminum, and copper test strips described in Table 2 in accordance with Section D9.

TABLE 2—*Corrosion Losses*

TEST STRIP	MAXIMUM PERMISSIBLE CORROSION LOSS Mg per Sq Cm of Surface
Tinned iron, electrolytic tin plating, 1.25 lb per base box	0.7
Steel, SAE 1010 (cold rolled)	0.7
Aluminum, SAE 24	0.2
Cast iron, SAE 111 (smooth machine surface)	0.7
Brass, SAE 70B	0.5
Copper, SAE 71	0.5

C3—Rubber Swelling—The increase in the base diameter of the cups after 120-hr exposure to the fluid, as described in Section D10, shall be not less than 0.005 in. and not more than 0.050 in. The surface of the rubber shall not be tacky or show any sloughing as indicated by carbon black on the surface.

C4—Compatibility—No liquid stratification or precipitation shall be evident the fluid is tested according to Section D11.

C5—Lubrication—At the end of the stroking test outlined in Section D12, the metal parts shall be free from excessive wear, corrosion, or galling. The rubber parts shall be in a satisfactory operating condition. Excessive leakage past the pistons shall be cause for rejection of the fluid. If corrosion of pistons occurs during stroking, analysis should be made of the piston to determine whether it is a suitable aluminum alloy.

C6—Residue—When tested in accordance with Section D13, the brake fluid shall cause no rust or corrosion of the metal parts and shall show no dry, hard, or gummy residue, or no substantial amount of sludge.

C7—Evaporation—Percentage—Not more than 80% (by weight) of the hydraulic-brake fluid shall be evaporated when it is subjected to the test described in Section D5.

Quality of Residue—The residue from the evaporation test described in Section D5 shall be fluid and oily and shall contain not more than a slight precipitate. Any such precipitate shall not feel gritty when rubbed against the test container with the finger tip. The residue shall remain fluid and oily while held at 32 ± 2 F for 2 hr.

D—Methods of Test—The fluid sample shall be tested, using the methods prescribed in Sections D1 to D13 inclusive.

D1—Viscosity—The viscosity of the fluid shall be determined in a capillary pipette according to procedure outlined by ASTM D 445.

D2—Cold Tests

(a) The cold test shall be determined by immersing a 125-cc oil-sample bottle containing 100 cc of the fluid in a bath which shall be maintained at −40 F for six days. At the end of this period the bottle is to be tilted from the vertical to the horizontal position, and the time that flow begins is to be recorded.

(b) The freezing point shall be determined by maintaining a 125-cc oil-sample bottle containing 100 cc of the fluid at −60 F for 6 hr. At the end of this period, the bottle is to be tilted from the vertical to the horizontal position, and the time that flow begins is to be recorded.

D3—Boiling Point—The apparatus required (Fig. 1) consists of a 100-cc round-bottom shortneck flask having a 19/38 female ground-glass joint, and a 10 mm outside diameter side-entering tube, a 400-F thermometer accurately calibrated for 3-in. immersion, and a straight-tube 200-mm jacket-length Liebig condenser, equipped with a 19/38 drip-tip male ground-glass joint at its lower end. Also three or four pieces of unglazed porcelain, each about 4 mm in diameter, are required. These are made by breaking up a porous plate made of unglazed porcelain, their function being to prevent superheating during the test.

A 60-cc sample of the fluid together with three or four pieces

of porous plate shall be placed in the flask, the condenser attached, and the thermometer inserted through the side tube to within ¼ in. of the bottom center of the flask. A seal shall be made around the thermometer with a short piece of rubber tubing. The flask shall be mounted on an asbestos-centered wire gauze and the whole assembly held in place by a clamp. The condenser water is turned on and heat applied by a bunsen burner or electric heater at such a rate that the fluid is brought to its boiling point in 10 min. The rate of reflux is then adjusted over another 10-min period to approximately 1 drop of reflux per sec. The temperature is then read, and after being corrected for barometric pressure according to ASTM D 86, it is taken as the boiling point.

Fluids boiling above 300 F may be considered satisfactory if a new sample is not refluxing at a greater rate than 1 drop per sec after being held at 300 F for 10 min.

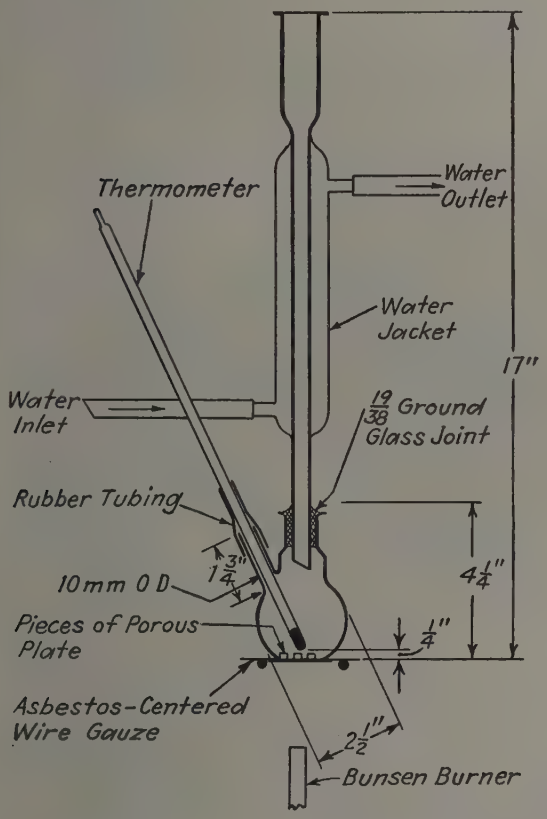


FIG. 1—APPARATUS FOR DETERMINING BOILING POINT

D4—Flash Point—The flash point of the fluid shall be obtained in accordance with ASTM D 92.

D5—Evaporation—Percentage—Evaporation of the fluid shall be determined by placing a 10-ml sample in a Petri dish of approximately 3½-in. diameter and weighing to the closest 0.01 gm. The Petri dish and fluid shall then be placed in a 210 ± 2 F air bath, free from drafts, for 48 hr. After this time the Petri dish shall be removed from the air bath and allowed to cool and reweighed to determine the weight of the fluid remaining. The per cent evaporation shall be calculated as follows:

$$\text{Per cent evaporation} = \frac{W - R}{W} \times 100$$

where R = weight of residue after heating
W = initial weight of sample

Quality of Residue—The residue remaining after the test outlined in Section D5 (percentage) shall be examined for fluidity and oiliness and for the amount and nature of the precipitate. The residue shall then be held at a temperature of 32 ± 2 F for 2 hr and then examined for fluidity and oiliness.

D 6—Water Tolerance—A 100-cc sample of the fluid shall be mixed with 3½ cc of water. The mixture shall be maintained at temperatures of 140 and −40 F for a period of 24 hr each and examined for stratification and precipitation.

D7—Neutrality—The pH shall be determined by the electrometric method. To the fluid is added 5% (by volume) of distilled water and 100% (by volume) of an 80% ethyl alcohol, 20% water mix, which mix shall have been adjusted to 7.0 pH. The pH is to be taken at a fluid mixture temperature of 75 ± 15 F.

D—Alternative Method—If the fluid is miscible with an equal volume of water, then water may be used in place of the above alcohol-water mixture.

D8—Corrosion—The corrosion test shall be carried out as follows:

The test strips, each of 20–35 sq cm area (approximately 3½ x ½ x ⅛ in.), shall be freed of scale, dirt, or oxidation products by polishing with a wire brush, steel wool, or soap and water as required, washed in water, then in alcohol, blown dry with air, and brought to equilibrium in a desiccator. (Do not use wire brush or steel wool on tinned-iron test strips.) The strips shall be weighed to the nearest 0.1 mg. The weighed strips, arranged in the order of tinned iron, steel, aluminum, cast iron, brass, and copper, shall be joined in metal-to-metal contact by fastening with a steel bolt or cotter pin passed through holes drilled near one end of each strip. The strips shall be so bent that, except for the small terminal area near the bolt or cotter pin, the strips shall not be in direct contact one with another. The strips shall then be inserted into a one-pint Mason jar in such manner that the bolted ends shall rest within the concavity of a new Lockheed FC-666-XO (compound 7712K) rubber cup. The 350 cc of the fluid to be tested, diluted with 5% (by volume) of distilled water, and heated to approximately 200 F, shall then be poured into the test jar to submerge totally the test-strip assembly. The glass cover shall then be clamped on in a vapor-tight manner with the aid of a conventional Mason-jar rubber gasket and the test vessel held for 120 hr in an oven at 210 ± 5 F. At the end of the test period the strips are to be removed, the adhering fluid flushed off with water, the individual strips disengaged one from the other and cleaned to remove any adhering corrosion products. The strips shall first be washed with a cloth wet with a 1:1:1 mixture of ethyl alcohol, acetone, and benzol to remove varnish, lacquer, and similar coatings. Coarse abrasives such as wire brushes or steel wool shall not be used for polishing following the corrosion test, but a mild abrasive such as Lava soap is permitted if solvent or mild nonabrasive soap washing does not produce bright strips. Polishing is completed by rinsing in water, then in alcohol, drying with a jet of air, and bringing to equilibrium in the desiccator. The polished strips then be weighed to the nearest 0.1 mg. The corrosion loss is

determined by subtracting from the difference in weights before and after the test, the loss resulting from polishing only. This "polishing only" loss may be assumed to be zero if a mild abrasive was not employed. If such a mild abrasive be required for cleaning, the "polishing only" loss shall be determined by subjecting an unused strip which has been well polished and weighed to a second polishing under as nearly as possible the polishing conditions employed on the strips after removal from the corrosion-test jar. The weight loss caused by this second polishing is the "polishing only" loss.

The average of three tests shall be the corrosion loss.

D9—Stability—A 70-cc sample of fluid together with a trisected Lockheed Manhattan FC-666-XO (compound 7712K) rubber cup and test strips of steel, aluminum, and copper, each approximately 5 sq cm in area (described in Table 2) is placed in boiling-point equipment (described in Section D3) and held at 295 F for 6 hr. After being held at 295 F for 6 hr, the boiling point shall not be less than 295 F.

D10—Rubber Swelling—Absorption of liquid by rubber cups and washers used in hydraulic-brake systems shall be tested as follows:

Cups—The cups used shall be 1¼-in. Lockheed Manhattan FC-666-XO (compound 7712K) and should not be more than three months old from date of production. Cups shall be free of lint and dirt, the base diameter determined to the nearest thousandth of an inch with a micrometer, and the diameter re corded. In measuring base diameter of a cup, care shall be take that the micrometer does not extend more than 1/32 in. beyon the bottom edge of the cup. The diameter shall be taken as a average of two readings at right angles to each other. If thes two diameters differ more than 0.003 in., the cup shall be dis carded.

Procedure—Two cups whose base diameters have been meas ured, shall be immersed in 75 cc of the fluid under test, in a 8-oz screw-cap glass bottle and held at a temperature of 15 ± 2 F for a period of 120 hr. After 120-hr exposure, the cups sha be removed from the bottle, washed quickly with ethyl alcoho dried with a clean cloth, and measured across the base with micrometer as before. This measurement shall be within 5 c 10 min after taking the cup out of the fluid. The surface of th cups shall be visually examined.

D11—Compatibility—Fifty-fifty mixtures of the fluid wit fluids currently used in new car production meeting SAE brake fluid specifications shall be prepared and held at 140 and −3 F for 24 hr. The mixtures are then examined for evidence o stratification or precipitation.

D12—Lubrication—The following test procedure is intende for use in evaluating the lubricating quality of the brake fluid

(*Text continued on next page.*)

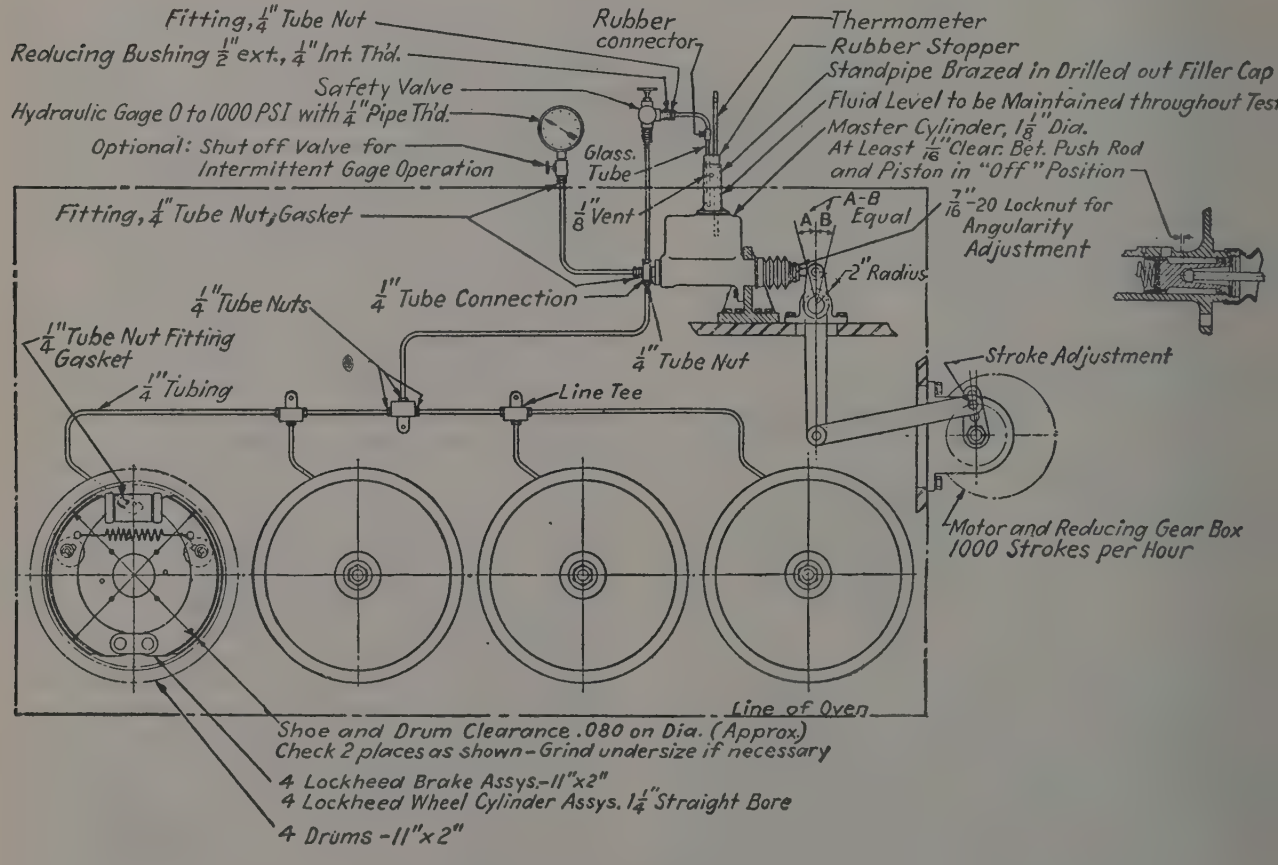

Fitting, 1/4" Tube Nut
Reducing Bushing 1/2" ext., 1/4" Int. Th'd.
Safety Valve
Hydraulic Gage 0 to 1000 PSI with 1/4" Pipe Th'd.
Optional: Shut off Valve for Intermittent Gage Operation
Glass Tube
Rubber connector
Thermometer
Rubber Stopper
Standpipe Brazed in Drilled out Filler Cap
Fluid Level to be Maintained throughout Test
Master Cylinder, 1 1/8" Dia.
At Least 1/16" Clear. Bet. Push Rod and Piston in "Off" Position
Fitting, 1/4" Tube Nut, Gasket
1/8" Vent
A-B Equal
A B
7/16"-20 Locknut for Angularity Adjustment
2" Radius
1/4" Tube Nuts
1/4" Tube Connection
1/4" Tube Nut Fitting Gasket
1/4" Tubing
1/4" Tube Nut
Line Tee
Stroke Adjustment
Motor and Reducing Gear Box 1000 Strokes per Hour
Line of Oven
Shoe and Drum Clearance .080 on Dia. (Approx.)
Check 2 places as shown - Grind undersize if necessary
4 Lockheed Brake Assys.-11"x2"
4 Lockheed Wheel Cylinder Assys. 1 1/4" Straight Bore
4 Drums -11"x2"

FIG. 2—STROKING-TEST APPARATUS

1. The apparatus shall consist of:

(a) One hydraulic-brake system master cylinder of 1⅛-in. diameter.

(b) Four brake assemblies having 1¼-in. diameter wheel cylinders, together with brake drums.

(c) A pressure relief or safety valve set for operation at a pressure of 500 ± 50 psi.

(d) A pressure gage satisfactory for operation at a pressure of 500 ± 50 psi.

(Note—A diagrammatic sketch of a suitable form of apparatus is shown in Fig. 2 and a list of parts typical of those which may be employed for assembly of the apparatus is given in the Appendix.)

2. The master- and wheel-cylinder castings shall be of cast iron, and the pistons shall be of a suitable aluminum alloy.

3. Fifteen feet of ¼-in. outside diameter copper tubing shall be used in assembling the apparatus.

4. The apparatus shall be enclosed in a heated air bath controlled to a temperature of 158 ± 5 F in the fluid in the master-cylinder reservoir.

5. Mechanical application of pressure to the master push rod shall be employed to simulate operation on the vehicle as closely as possible.

6. All rubber parts shall be of natural rubber (Lockheed Manhattan compound 7712K).

(Note—At present the manufacturer and supplier of these rubber parts is the Manhattan Rubber Manufacturing Division of Raybestos-Manhattan Company, Inc., Passaic, New Jersey, under the branding reference XO. Parts should be ordered in accordance with the part numbers listed below.)

Part	*Part Number*
Master-cylinder primary cup	FD-2398 (XO)
Master-cylinder secondary cup	FD-2399 (XO)
Compensator check valve	FC-3578 (XO)
Wheel-cylinder cups	FC-666 (XO)

(Note—New master- and wheel-cylinder units shall be purchased unassembled and must not be used for more than one test. No parts shall be used in any test unless these are in satisfactory condition on inspection prior to assembly of the apparatus. New rubber cups which shall not be more than three months old from date of manufacture must be employed for each test.)

Test Procedure—The test procedure to be employed is as follows:

1. The rubber and metal test parts shall be washed or flushed with a proprietary methyl or ethyl alcohol, dried, and inspected for corrosion or other defects.

2. The fluid lines shall be cleaned and flushed with a proprietary methyl or ethyl alcohol and blown dry with dry air.

3. Immediately after inspection, the test parts shall be dipped into and coated with the fluid to be tested, the apparatus assembled, and the test conducted promptly.

4. The test fluid shall then be introduced into the apparatus and the system bled free of air.

5. The stroke of the master-cylinder push rod shall be adjusted to be as nearly as possible along the centerline of the cylinder to avoid side thrust and excessive wear.

6. At the start of the test the brake shoes shall be adjusted concentric with the brake-assembly axis to provide a diametral clearance of 0.080 in. between the shoes and the drums (0.040-in. clearance on each side).

7. The stroke shall be adjusted to give a maximum pressure of 500 ± 50 psi as measured by a pressure gage installed in the fluid line.

8. Stroking shall be at the rate of 1000 ±100 strokes per hr and the tests shall be continued for a total of 150,000 strokes.

9. At the end of the test the condition of the parts as disassembled shall be noted, following which the parts shall be washed with a proprietary methyl or ethyl alcohol and further inspected immediately.

10. If mechanical difficulties which cannot be attributed to the fluid are encountered during the test, the test shall be repeated.

D13—Residue—A complete brake-wheel cylinder assembly (1 to 1¼ in. in diameter), except boots, having an iron housing and aluminum pistons shall be used for the test. It shall be carefully cleaned to remove all traces of residual brake fluid or rust-preventive oil. After cleaning, the parts shall be rinsed with ethyl alcohol and dried. All parts shall then be assembled using a wire or clamp to hold the pistons approximately ¼ in. inside the cylinder. While assembling, each part shall be dipped into the brake fluid under test. After assembly, 5 ml of the brake fluid under test shall be added to the assembly through the inlet connection. The bleeder opening shall be tightly closed. With the inlet connection fitting removed, the assembly shall be placed in an oven with the bleeder connection in an upward position. The assembly shall be kept in the oven at temperature of 158 ± 5 F for fourteen days. After the fourteen days, the assembly shall be carefully disassembled to observe conformance with the requirements specified in Section C6.

Moderate-Duty Type (SAE R 72)

E—Type—These specifications cover brake fluids of the non-mineral oil type for use in the atmospheric range of approximately 130 to −20 F in highway vehicles where the brake fluid is not exposed to severe operating conditions.

F—Material—The materials used shall be such that the resulting compound will conform to the requirements of this specification.

G—Detail Requirements—Hydraulic-brake fluids covered by these specifications shall be in accordance with Table 2 and Table 3, and Sections G1, G2, G3, G4, G5, G6, and G7.

G1—Corrosion—Same requirements as in Section G1.

G2 Stability—The boiling point shall not be less than 225 F after the fluid has been held at 225 F for 6 hr in the presence of a rubber cup (Lockheed Manhattan FC-666-XO) and steel, aluminum, and copper test strips described in Table 2 in accordance with Section H9.

G3—Rubber Swelling—Same as Section C3.

G4—Compatibility—No liquid stratification, but slight precipitation may be evident when the fluid is tested according to Section H11.

G5—Lubrication—Same as Section C5.

G6—Residue—Same as Section C6.

G7—Evaporation—Percentage—Not more than 85% (by weight) of the hydraulic-brake fluid shall be evaporated when it is subjected to the test described in Section H5.

Quality of Residue—The residue from the evaporation test described in Section H5 shall be fluid and oily and shall contain

not more than a slight precipitate. Any such precipitate shall not feel gritty when rubbed against the test container with the finger tip. The residue shall remain fluid and oily while held at 32 ± 2 F for 2 hr.

TABLE 3—*Required Tests for SAE R 72*

TESTS	TEST LIMITS
Viscosity (kinematic) at −20 F, max	1000 centistokes
Viscosity (kinematic) at 130 F, min.	3.5 centistokes
Cold test (24 hr at −20 F)	Shall begin to flow within 5 sec after the sample bottle is tilted from the vertical to horizontal position. No stratification. Slight precipitation permitted.
Boiling point, F, min	230
Flash point, F, min	100
Water tolerance (3.5 cc of water at 120 and −10 F)	Shall begin to flow within 5 sec after the sample bottle is tilted from the vertical to horizontal position. No stratification. Slight precipitation permitted.
Neutrality	pH 5.0 to 9.5
Neutrality (after corrosion test)	pH 5.0 to 9.5

H—Methods of Test—The fluid sample shall be tested using the methods prescribed in Sections H1 to H13 inclusive.

H1—Viscosity—Same as Section D1. The viscosity of the fluid shall be determined in a capillary pipette according to procedure outlined by ASTM D 445.

H2—Cold Test—The cold test shall be determined by immersing a 125-cc oil-sample bottle containing 100 cc of the fluid in a bath which shall be maintained at −20 F for 24 hr. At the end of this period the bottle is to be tilted from the vertical to the horizontal position, the time that flow begins is recorded, and the material is examined for stratification and precipitation.

H3—Boiling Point—The apparatus required (Fig. 1) consists of a 100-cc round-bottom, shortneck flask having a 19/38 female ground-glass joint and a 10-mm outside diameter side-entering tube, a 400-F thermometer accurately calibrated for 3-in. immersion, and a straight-tube 200-mm jacket-length Liebig condenser, equipped with a 19/38 drip-tip male ground-glass joint at its lower end. Also three or four pieces of unglazed porcelain, each about 4 mm in diameter are required. These are made by breaking up a porous plate made of unglazed porcelain, their function being to prevent superheating during the test.

A 60-cc sample of the fluid together with three or four pieces of porous plate shall be placed in the flask, the condenser attached, and the thermometer inserted through the side-tube to within ¼ in. of the bottom center of the flask. A seal is to be made around the thermometer with a short piece of rubber tubing. The flask is mounted on an asbestos-centered wire gauze and the whole assembly held in place by a clamp. The condenser water is turned on, and heat is applied by a bunsen burner or electric heater at such a rate that the fluid is brought to its boiling point in 10 min. The rate of reflux is then adjusted over another 10-min period to approximately 1 drop of reflux per sec. The temperature is then read, and after being corrected for barometric pressure according to ASTM D 86, it is taken as the boiling point.

Fluids boiling above 230 F may be considered satisfactory if a new sample is not refluxing at a greater rate than 1 drop per sec after being held at 230 F for 10 min.

H4—Flash Point—Same as Section D4.

H5—Evaporation—Same as Section D5.

H6—Water Tolerance—A 100-cc sample of the fluid shall be mixed with 3½ cc of water. The mixture shall be maintained at a temperature of 120 and −10 F for a period of 24 hr each. At the end of this period the bottle is tilted from the vertical to horizontal position, the time flow begins is recorded, and the material is examined for stratification and precipitation.

H7—Neutrality—Same as Section D7.

H8—Corrosion—Same as Section D8.

H9—Stability—A 70-cc sample of fluid together with a trisected Lockheed Manhattan FC-666-XO (compound 7712K) rubber cup and the test strips of steel, aluminum, and copper, each approximately 5 sq cm in area (described in Table 2) is placed in boiling-point equipment and held at 225 F for 6 hr. After being held at 225 F for 6 hr, the boiling point shall not be less than 225 F.

H10—Rubber Swelling—Same as Section D10.

H11—Compatibility—Fifty-fifty mixtures of the fluid with fluids currently used in new car production and meeting SAE brake-fluid specifications are prepared and held at 140 and −20 F for 24 hr. The mixtures are then examined for evidence of stratification or precipitation.

H12—Lubrication—Same as Section D12.

H13—Residue—Same as Section D13.

Appendix

Apparatus—A list of parts which may be employed in the assembly of the apparatus is as follows:

Master Cylinder—1⅛-in. diameter, to include cast-iron cylinder, aluminum-alloy piston, and natural-rubber valves, and cups of XO compound (one required).

(Such a master cylinder is manufactured by the Wagner Electric Corp., St. Louis, Mo., Part No. FE-1193.)

Brake Assembly—11 x 2 in. with shoes and lining, but without wheel cylinders (four required).

(Such a brake assembly is manufactured by the Wagner Electric Corp., St. Louis, Mo., Part No. FE-2636, less wheel cylinder.)

Wheel Cylinder—1¼-in. diameter straight bore, to include cast-iron cylinder, aluminum-alloy pistons, and natural-rubber cups of XO compound (four required).

(Such a wheel cylinder is manufactured by the Wagner Electric Corp., St. Louis, Mo., Part No. FD-6769.)

Brake Drum—11 x 2-in. cast-iron rim steel backing (four required).

(Such a brake drum is manufactured by the Budd Manu-

facturing Co., Philadelphia, Pa., Part No. 8388.)

Hydraulic Gage—4½-in. dial face, satisfactory for operation at 500 ± 50 psi (one required).

(Such an hydraulic gage is manufactured by Ashcroft, Part No. 0–1000 No. 1079E, 4½-in. dial face.)

Shutoff Valve—¼-in. (one required) optional.

(Such a shutoff valve is manufactured by the Crane Co., Chicago, Ill., Part No. 222H, ¼ in.)

Safety Valve—½ in. (one required).

(Such a safety valve is manufactured by the Crane Co., Chicago, Ill., Part No. 1128, ½ in.)

Pipeline—¼-in. outside diameter copper or steel tubing, line tees, bushings, tube nuts, gaskets, and fittings (one required).

Stroking Actuator—Motor and reducing-gear box or equivalent (one required).

Oven—Sufficient to handle apparatus in accordance with the specifications (one required).

Crankcase-Oil Classification

SAE Recommended Practice

Report of Miscellaneous Division approved June 1911 and last revised by Fuels and Lubricants Technical Committee October 1950.

[*The original specifications for crankcase oil, first adopted as Specification No. 26 in June 1911, gave specific gravity, flash, and fire tests, and carbon residue as well as viscosities. With subsequent growth and development in petroleum refining, the standard was extended in 1923 to include specifications for ten oils, including two with low pour test, classified on the basis of their viscosity ranges.*

This extended specification did not prove practical, however, because of the differences in characteristics of oils refined from different base crudes and the use of marketing designations such as "light" and "medium" which did not relate to oils of similar characteristics among the different brands. Consequently, in July 1926 a new classification was adopted under which oils were grouped on the basis of viscosity ranges only and other characteristics omitted. This was modified in January 1939; and effective May 15, 1950, the SAE 60 and 70 grades in the January 1939 version of the classification were cancelled. Effective October 3, 1950, the entire classification was revised and supplemented by discontinuing the SAE 10 grade and including the SAE 5W, 10W, and 20W grades. For the previous classification, the use of which is optional for 18 months after revision, see the 1950 SAE Handbook, SAE Recommended Practice for Crankcase Oil Classification.]

The SAE viscosity numbers constitute a classification for crankcase lubricating oils in terms of viscosity only. Other factors of oil character or quality are not considered.

Viscosity numbers without an additional symbol are based on the viscosity at 210 F.

Viscosity numbers with the additional symbol "W" are based on the viscosity at 0 F.

The viscosity of oils included in this classification for use in crankcases shall not be less than 39 sec at 210 F, Saybolt Universal.

Viscosity values are given in Table 1.

TABLE 1—*Viscosity Values for Crankcase Oils*

SAE VISCOSITY NUMBER	VISCOSITY RANGE, SAYBOLT UNIVERSAL, SEC			
	at 0 F		at 210 F	
	Minimum	Maximum	Minimum	Maximum
5W	—	4,000	—	—
10W	6,000[a]	less than 12,000	—	—
20W	12,000[b]	48,000	—	—
20	—	—	45	less than 58
30	—	—	58	less than 70
40	—	—	70	less than 85
50	—	—	85	110

[a] Minimum viscosity at 0 F can be waived provided viscosity at 210 F is not below 40 sec, Saybolt Universal.

[b] Minimum viscosity at 0 F can be waived provided viscosity at 210 F is not below 45 sec, Saybolt Universal.

In the case of prediluted oils, SAE viscosity numbers by which the oils are classified shall be determined by the viscosity of the undiluted oils.

Wherever the SAE viscosity numbers are used on prediluted oils, the container labels should show in some suitable manner that the SAE number applies to the undiluted oil.

Effective Dates of Revisions

SAE General Information

Report of Lubricants Division approved January 1942 and last revised by Fuels and Lubricants Technical Committee January 1949.

[*The policy of this SAE General Information was adopted in order to minimize disturbances in marketing oils.*]

When a new lubricant classification is recommended by the Technical Committee, it shall be effective in use immediately upon approval by the Society. When an existing classification is modified or cancelled, field application immediately following adoption of such changes is optional but shall be fully effective eighteen months after such adoption.

Temperatures for Recommending Crankcase Oils

SAE General Information

Report of Lubricants Division approved January 1942 and last revised by Fuels and Lubricants Technical Committee January 1949.

Since viscosity is recognized as the most important single factor, the selection of a winter crankcase oil must be based on the lowest anticipated atmospheric temperature, while the selection of a summer lubricant should be based on the higher temperatures expected during the day.

TABLE 1—*Temperatures for Recommending Crankcase Oils*

ANTICIPATED MINIMUM TEMPERATURES,[a] F				DAYTIME TEMPERATURES, F
Less than −10	−10	+10	32	Above 90

[a] Basis for engine starting conditions.

Crankcase-Oil Viscosities

SAE General Information

Report of Lubricants Division approved January 1941 and last revised by Fuels and Lubricants Technical Committee January 1949.

[*In view of the need for a uniform method of determining the low-temperature viscosity of oils, the Lubricants Division recommended to the American Society for Testing Materials that a standard viscosity temperature chart be developed. ASTM Chart D 341—32T was endorsed in June 1933 by the Division and the Society for use in the automotive industry. Subsequent changes were endorsed in January 1938. The revised ASTM Charts referred to in this General Information were endorsed by the Fuels and Lubricants Technical Committee in June 1947*].

Viscosity Temperature Charts—Viscosities at temperatures other than standard ASTM viscosity temperatures shall be determined by extrapolation or interpolation of ASTM Charts D 341—43.

Note—The following charts (comprising ASTM D 341) are available from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

Chart A—Saybolt viscosities of 33 to 100,000,000 sec; −30 to +450 F (size 20 x 16 in.).

Chart B—Saybolt viscosities of 33 to 100,000 sec; −30 to +350 F (size 8½ x 11 in.).

Chart C—Kinematic viscosities of 2.0 to 20,000,000 centistokes; −30 to +450 F (size 20 x 16 in.).

Chart D—Kinematic viscosities of 0.40 to 100 centistokes; −30 to +450 F (size 20 x 20 in.).

Chart E—Kinematic viscosities of 2.0 to 20,000,000 centistokes; −100 to +450 F (size 26 x 20 in.).

Method of Estimating Viscosity at 0 F—The viscosity at 0 F of engine crankcase oils and transmission and rear-axle lubricants shall be estimated by extrapolation on the ASTM Viscosity Temperature Charts, ASTM D 341—43, from kinematic viscosities determined by the Tentative Method of Test for Kinematic Viscosity, ASTM D 445—46T, at two temperatures that are at least 60 F apart (for example, 70 and 130 F or 100 and 210 F) or from Saybolt viscosities determined by the Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter, ASTM D 88—44, at 70 and 130 F in the case of low-viscosity engine crankcase oils (below SAE 30) and at 100 and 210 F in the case of high-viscosity engine crankcase oils and transmission or rear-axle lubricants.

The error in estimating viscosities at 0 F is cumulative and is far greater than the errors in individual viscosity determinations. Assuming absolute accuracy in extrapolating on the viscosity temperature chart, an error of ±0.5% in the viscosity determinations at 100 and 210 F may result, in the case of an oil having a viscosity of 12,000 sec at 0 F, in an error

of 10 to 15% in the estimated viscosity at 0 F. To this error, resulting solely from errors in viscosity determinations, must be added the actual error involved in the process of extrapolation, which should not exceed an additional 15%. With proper attention to details of procedure outlined in the ASTM methods, the estimated viscosity at 0 F, reported by experienced operators working in different laboratories with standardized equipment, should not differ more than the amounts shown as follows:

Estimated Viscosity at 0 F Extrapolated from	*Maximum Error in Estimated Viscosity at 0 F*
Saybolt viscosities determined at 100 and 210 F	±20%
Saybolt viscosities determined at 70 and 130 F	±10%
Kinematic viscosities determined at 100 and 210 F	±10%
Kinematic viscosities determined at 70 and 130 F	±5%

If the viscosity at 0 F is extrapolated from kinematic values determined at 100 and 210 F or from Saybolt values determined at 70 and 130 F, in accord with the recommended practice, the error in the estimated viscosity at 0 F may be as high as ±10%. Therefore, an oil having an estimated viscosity of 12,000 SUS on the old chart and 12,000 SUS on the new chart may be reported as high as 13,200 Saybolt sec. If the viscosity at 0 F is extrapolated from Saybolt values determined at 100 and 210 F (this practice is not recommended because of the difficulty of accurately determining Saybolt viscosity at 210 F), the error may be as high as ±20%, and an oil having an estimated viscosity of 12,000 SUS at 0 F on the chart may be reported as high as 14,400 SUS without any actual change in the viscosity of the lubricant.

Crankcase-Oil Types

SAE General Information

Report of Fuels and Lubricants Technical Committee approved February 1947.

[*This SAE General Information relating to the American Petroleum Institute crankcase-oil type definitions was prepared by the SAE Fuels and Lubricants Technical Committee to assist the users of automotive equipment in the selection of oils for the operating conditions described.*]

Up to 1945, automotive crankcase oils were classified in terms of viscosity only, other factors of oil quality or character not being considered. By that time, developments in refining methods and treatments had led to an increased variety of oils which the Lubrication Committee, Division of Marketing of the American Petroleum Institute, has designated as follows:

"**Regular Type**—This term designates motor oil generally suitable for use in internal-combustion engines under moderate operating conditions."

"**Premium Type**—This term designates motor oil having the oxidation stability and bearing corrosion-preventive properties necessary to make it generally suitable for use in internal-combustion engines where operating conditions are more severe than regular duty."

"**Heavy-Duty Type**—This term designates motor oil having the oxidation stability, bearing corrosion-preventive properties, and detergent-dispersant characteristics necessary to make it generally suitable for use in both high-speed diesel and gasoline engines under heavy-duty service conditions."

Moderate or Average Conditions—For years many passenger-car and truck engines have been lubricated with motor oils which are now designated by API as Regular-Type motor oils. The majority of gasoline engines in use today, particularly in passenger cars, when operated under ordinary driving conditions can continue to be serviced with such oils as satisfactorily as in the past.

More Severe Conditions—As ordinarily used, the engine of a passenger car is seldom required to develop its full power. If, however, the same engine is used in a different type of service, as in mountain climbing, fast acceleration, or sustained high-speed driving, or is installed in a light truck, bus, tractor, motorboat, or industrial equipment, it may have to operate at full power or more nearly full power for a much larger percentage of the time. Under these conditions the temperature of practically all operating parts of the engine will be higher than in the same engine when used under moderate or average driving conditions. Excessive heating is harmful to all lubricating oils because under elevated temperatures oxygen combines with the oil forming oxidation products to a greater or lesser extent depending on conditions. These oxidation products will contaminate the oil and may form harmful deposits on vital engine parts. Oils having improved stability and oxidation resistance may accordingly be required under these conditions. Such oils will give satisfactory service under moderate as well as the more severe conditions just described. API has designated oils of this type as Premium-Type motor oils.

Heavy-Duty Conditions—Oils possessing detergent qualities, in addition to improved oxidation resistance, may be required in many heavy-duty operations, such as prevail in sustained high-speed travel under heavy loads in some truck and bus operations. Oils of this type which have proved oxidation stability, bearing corrosion-resisting properties and detergent-dispersant characteristics, are designated by the American Petroleum Institute as Heavy-Duty Type oils. (As an example, oils that meet the

engine-test requirements of US Army Specifications 2-104B or the US Navy Specifications 14-0-13A, commonly known as the 9000 series, are designated as Heavy-Duty Type motor oils.) These oils are recommended for high-speed diesel engines and for gasoline engines in heavy-duty bus, truck, tractor, marine, or industrial service. Oils of this type are also in use under the moderate and more severe conditions described above, in accordance with the recommendation of the equipment manufacturer or the oil supplier.

Other Factors Related to Oil Performance—Satisfactory performance of engines in service is dependent upon five factors: operating conditions, maintenance, engine design, fuel, and lubricating oil.

Although the crankcase oil is an important factor in engine performance, each of the other items is also vitally important. Satisfactory engine performance requires the utmost care in proper selection of the oil and continual attention to the other factors.

Engine Tests for Evaluating Crankcase Oils

SAE General Information

Report of Lubricants Division approved January 1942 and last revised by Fuels and Lubricants Technical Committee January 1950.

In December 1934, Subdivision B, Effect of Lubricants on Bearing Metals, was appointed under the SAE Lubricants Division to study the effects of chemical composition of crankcase oils on bearings, primarily the copper, lead, and cadmium types. At the request of the Subdivision, Committee D-2 of ASTM appointed a collaborating Subcommittee on Corrosion Tests of Lubricating Oils, and the first progress report[1] was presented at the ASTM Annual Meeting in June 1937. In January 1940 the Subdivision was changed to Subdivision B, Effect of Stability on Performance of Lubricants, and soon thereafter an Automotive Group and a Petroleum Group were designated to study their respective phases of the project.

Through a comprehensive series of tests[2] in which the laboratories of a number of automotive and petroleum companies cooperated, an engine test for measuring bearing corrosion and for determining the oxidation resistance of crankcase oils was developed. The principles of this test were approved by the SAE Lubricants Division and the method was referred to the ASTM for standardization. It was published for information by the ASTM in the 1942 Report of ASTM Committee D-2.[3]

Cooperative research in connection with this test and engine tests to measure other properties of the oil, such as detergency, ring-sticking, and piston scuffing, is being carried out under the direction of the coordinating Lubricants and Equipment Research Committee of the Coordinating Research Council, Inc. 30 Rockefeller Plaza, New York 20, N. Y., from whom the latest information on these and similar research techniques may be obtained

[1] Tests to Determine the Corrosive Properties of Oils as Related to Bearing Metals. Report to ASTM Committee D-2, Subcommittee I on Corrosion Tests of Lubricating Oils, June 28, 1937.

[2] The Testing of Heavy-Duty Motor Oils, by H. C. Mougey and J. A. Moller, API, November 3–7, 1941 and SAE, January 16, 1942. Published in SAE Transactions, Vol. 50, October, 1942, pp. 417–438.

[3] ASTM Proceedings, Vol. 42, 1942, pp. 326–340. Proposed Method of Test for Oxidation Characteristics of Heavy-Duty Crankcase Oils.

Transmission- and Axle-Lubricant Classification

SAE Recommended Practice

Report of Lubricants Division approved February 1924 and last revised by Fuels and Lubricants Technical Committee September 1948.

The SAE viscosity numbers for transmission and rear-axle lubricants constitute a classification in terms of viscosity and of consistency at low temperatures only. Other factors of quality or character are not considered. See Table 1 for viscosity values.

In the case of SAE 80, the minimum viscosity limit is not specified since this grade is special for use at very low temperatures at which SAE 90 would be too heavy. The oil company furnishing the lubricant shall be responsible for maintaining a sufficiently high minimum viscosity to provide satisfactory lubrication. In a similar manner the maximum viscosity limit for SAE 250 is not specified, since this grade is a special one for temperatures at which SAE 140 is too light. The oil company furnishing this lubricant shall be responsible for maintaining a sufficiently low maximum viscosity to provide satisfactory shifting of gears without channeling at the lowest temperature for which the lubricant is recommended.

In the case of fluid grease made by adding soap or other thickening ingredients to oil, the viscosity number by which the lubricant is classified shall be determined by the viscosity of the oil before the addition of the soap or other thickening ingredients.

TABLE 1—*Viscosity Values for Transmission and Axle Lubricants*

SAE VISCOSITY NUMBER	VISCOSITY RANGE, SAYBOLT UNIVERSAL	CONSISTENCY, MUST NOT CHANNEL IN SERVICE AT
80	100,000 sec at 0 F, max	−20 F
90	800 to 1500 sec at 100 F	0 F
140	120 to 200 sec at 210 F	+35 F
250	200 sec at 210 F, min	

A cross index of SAE designations for materials and parts appears after the last standard in this book.

Temperatures for Recommending Gear Lubricants

SAE General Information

Report of the Fuels and Lubricants Technical Committee approved January 1951.

Viscosity is recognized as a very important factor in the proper functioning of a gear lubricant, not only for high operating temperatures but also for lowest anticipated atmospheric temperatures. In recommending gear lubricants based on lowest anticipated atmospheric temperatures, the following are suggested as a uniform practice in making such recommendations:

+32 F +10 F −10 F

Transmission- and Axle-Lubricant Types

SAE General Information

Report of Lubricants Division approved February 1924 and last revised by Fuels and Lubricants Technical Committee January 1951.

[*This SAE General Information relating to the API-approved designations for automotive transmission and differential lubricants was prepared by the SAE Fuels and Lubricants Technical Committee to assist the users of automotive equipment in the selection of lubricants for the operating conditions described.*]

In transmissions and particularly in rear axles, gears of different designs are employed under a variety of different service conditions. Selection of a gear lubricant for any specific gear application for use under any specific service condition involves careful consideration of the lubrication requirements of the gears and the performance characteristics of the gear lubricant.

Gear sets which, because of design and application, operate under tooth pressures or rubbing velocities or both in excess of the safe limits for mineral oil alone necessitate the use of oils compounded with other materials for the purpose of maintaining an adequate factor of safety. The duty imposed on the lubricant by some gear sets in this class may be only slightly in excess of the load-carrying capacity of straight mineral oil, whereas in other cases it is greatly in excess.

All oils compounded to increase load carrying capacity may be identified as extreme-pressure lubricants. However, since the term extreme pressure means that the load carrying capacity is substantially greater than that of mineral oil of the same viscosity without any distinction as to how much greater it may be, it is necessary to indicate further the degree of load-carrying capacity required in the several types of gear sets.

Up to 1947, transmission and differential lubricants were described by a great variety of designations, each designation attempting to describe both the lubricant as well as the service conditions under which the lubricant must perform. Consolidation and subsequent simplification of the many variables encountered in transmission and differential lubricant testing have resulted in the development of designations for transmission and axle lubricants by the Lubrication Committee, Division of Marketing, API, approved by the General Committee of API November 11, 1947 and adopted by API January 27, 1948. These API type designations and their respective applications are as follows:

"**Regular-Type Gear Lubricant**—This term designates gear lubricants generally suitable for use in automotive transmissions[1] and in most spiral-bevel and worm-gear differentials."

"**Worm-Type Gear Lubricant**—This term designates gear lubricants generally suitable for use in truck-type worm-gear rear axles under very severe conditions of service."

"**Mild-Type EP Gear Lubricant**—This term designates gear lubricants having load-carrying properties suitable for many automotive transmissions[1] and spiral-bevel differentials under severe conditions of speed and load."

"**Multipurpose-Type Gear Lubricant**—This term designates gear lubricants having load-carrying properties suitable for hypoid gear and other types of differentials and many transmissions.[1]"

Service Applications—*Regular-Type Gear Lubricants*—In some gear sets, tooth pressures and rubbing velocities are low enough so that the gears can be satisfactorily lubricated with straight mineral oils. These oils are identified as Regular-Type Gear Lubricants.

Worm-Type Gear Lubricants—In some worm-gear sets, tooth pressures or rubbing velocities are such that they cannot safely be lubricated by regular-type gear lubricants. For lubricants designed to meet these extreme conditions a special designation has been developed. These lubricants are identified as Worm-Type Gear Lubricants.

Mild-Type EP Gear Lubricants—Some transmissions and particularly some spiral-bevel gear rear axles show a tendency to score and wear unduly when operated under extreme service conditions on regular-type gear lubricants. These gear sets may function satisfactorily on mild extreme-pressure lubricants which have load-carrying capacities in excess of regular-type gear lubricants.

Multipurpose-Type Gear Lubricants—Gears are in general use for which a lubricant having the highest possible load-carrying capacity is needed for most conditions of speed and torque. Typical of such gears are the hypoid type used in passenger cars and trucks. The multipurpose-type lubricants are designed to provide maximum protection at high speed in passenger-car

[1] "Transmissions of nonautomatic type require SAE 80, 90, 140, or 250 viscosity grade gear lubricants. Automatic or semiautomatic transmissions, fluid couplings, torque converters, and tractor hydraulic systems may require special lubricants. For the proper lubricant consult the manufacturer."

axles and maximum protection under the low-speed, high-torque conditions existing in heavy-duty truck service. These lubricants are also suitable for spiral-bevel differentials and many transmissions. Lubricants of this type are designated as Multipurpose-Type Gear Lubricants. The term multipurpose does not mean that a single viscosity grade may be used for all applications under all climatic conditions; the proper viscosity grade must be selected for each application.

For use in axles in regular service, the multipurpose-type gear lubricants have practically replaced those lubricants referred to in previous editions of the SAE Handbook as passenger-car type hypoid and truck-duty hypoid lubricants. The passenger-car type hypoid lubricant is still used by several manufacturers for the initial or factory fill of passenger-car hypoid rear axles.

Other Factors Related to Gear-Lubricant Performance—So far, no generally accepted method of test for determining the load-carrying capacity of the several types of gear lubricants on a common numerical scale has been developed to the point where it can be made the basis of an SAE classification. Full-scale tests under varying service conditions on gears of the type to be lubricated constitute the only satisfactory existing method of evaluating gear lubricant performance.

In addition to load-carrying capacity, each manufacturer of gear lubricants has to consider many other factors, of which some of the most important are considered in the following sections.

Viscosity—Viscosity determines ease of gear shifting and influences channeling at low temperatures. It has some bearing on load-carrying capacity, leakage, and in some instances, gear noise. The proper viscosity, regardless of the load-carrying ability of the lubricant, depends upon design and operating conditions, especially temperature. In general, for passenger-car service, one viscosity grade is satisfactory for year-round service; for trucks, buses, and other heavy-duty equipment, two viscosity grades are commonly recommended. However, for extremely low or high operating temperatures and for extremes in climatic conditions, a lower or higher SAE viscosity grade may be necessary.

The SAE Viscosity Numbers for transmission and rear-axle lubricants were selected to prevent confusion with the SAE numbering system for crankcase oils. Prior to 1950, SAE Viscosity Numbers for crankcase oils ranged from SAE 10 to SAE 70. The grade numbers chosen for gear lubricants were of a higher series, without regard to any relationship of actual viscosity ranges in the two series. Although the SAE viscosity grade numbers for gear lubricants are higher than those for crankcase oils, it does not necessarily follow that all gear lubricant grades are higher in viscosity than those for crankcase oils. For example, SAE 20 and 30 crankcase oils and SAE 80 gear lubricant may have the same viscosity characteristics; and, also, SAE 40 and 50 crankcase oils and SAE 90 gear lubricant may have similar viscosity characteristics. With the knowledge of viscosity and consistency of a motor oil at the temperatures at which the gear-lubricant classification is based, the compliance of a motor oil with a gear-lubricant classification grade can be determined. Such compliance is limited to SAE 80 and 90 grade gear lubricants, since the latest revision of the SAE Crankcase Oil Classification on October 3, 1950 does not include a grade with a viscosity higher than 110 at 210 F.

Channeling—It is of importance that under low-temperature conditions the lubricant should not "set" or "channel" but should flow readily between contacting surfaces. This is particularly so in the case of highly stressed gears such as hypoid and some spiral-bevel types where absence of lubricant even for a short period may result in rapid scoring or scuffing.

The pour point of a gear lubricant is not a complete index in determining whether the lubricant will feed satisfactorily and not channel at low temperatures. The viscosity of the lubricant and its characteristics when approaching solidification are the major influencing factors.

Stability and Oxidation Resistance—It is important that chemical and physical properties be maintained uniformly in storage. Abnormally high or low temperatures during storage may cause formation or separation of materials that may alter the original properties of the lubricant. Length of time and temperature in storage and also operating temperatures and mileage in service are major factors affecting properties of any lubricant.

For transmissions and rear axles of conventional construction in passenger cars and in normal conditions of service, temperatures of the lubricant may not be high enough to make resistance to oxidation of paramount importance. For severe conditions of service, particularly in trucks and buses where high temperatures occur, oils of superior oxidation resistance are generally to be preferred. This property is normally imparted to lubricants in greater degree by use of highly refined mineral oils in the lubricant.

Solid Matter—In general, lubricants containing solid materials in suspension are undesirable for ball or roller bearings in transmissions and rear axles. They may cause abrasion and wear.

Foaming—Excessive foaming of a lubricant in service is extremely objectionable. Excessive foaming will cause leakage and deplete the supply of lubricant in the housing.

Chemical Activity, Corrosion, and Wear—In order to obtain very high load-carrying capacity, chemical agents are usually employed as compounding ingredients. Such addition agents may introduce corrosion problems. However, blackening or darkening of brightly polished copper or other metal surfaces in contact with a lubricant does not necessarily indicate that the lubricant will cause harmful corrosion in service. Corrosion may be avoided by choice of a lubricant containing the proper combination of chemical additives.

It is also necessary that attention be given to the possibility that rate of wear on gears and bearings may be affected by the nature of the ingredients used to give high load-carrying capacity.

Mixing Gear Lubricants—When gear lubricants of different types are mixed, the load-carrying properties of the mixture will, in general, be intermediate to the load-carrying properties of the individual lubricants. For example, mixing a regular-type gear lubricant with a multipurpose-type gear lubricant will increase the load-carrying capacity of the regular-type gear lubricant but will decrease the load-carrying capacity of the multipurpose-type gear lubricant. The extent of this change in load-carrying capacity depends in part on the load-carrying capacity of the individual lubricants and on the relative amount of each present in the mixture. Other properties of the lubricants may be affected in a similar manner, whether the lubricants being mixed are new or used.

Corresponding Ranges in Kinematic, Redwood, and Engler Viscosities

SAE General Information

Report of Lubricants Division approved January 1940.

[The SAE viscosity numbers constitute classifications of lubricating oils in terms of Saybolt Universal viscosity only. Other factors of oil quality or character are not considered. The Saybolt Universal viscosities given in the SAE classifications are the official values. The corresponding Kinematic, Redwood, and Engler viscosities are approximate and are given for information only.]

TABLE 1—*Crankcase Oils*

SAE VISCOSITY NUMBERS	CENTISTOKES				REDWOOD				ENGLER			
	0 F		210 F		0 F		210 F		0 F		210 F	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
5W	—	871	—	—	—	3500	—	—	—	115	—	—
10W	1307	2614	—	—	5250	10500	—	—	172	344	—	—
20W	2614	10458	—	—	10500	42000	—	—	344	1376	—	—
20	—	—	5.75	9.65	—	—	40.9	51.6	—	—	1.46	1.80
30	—	—	9.65	12.98	—	—	51.6	61.9	—	—	1.80	2.12
40	—	—	12.98	16.82	—	—	61.9	75.2	—	—	2.12	2.52
50	—	—	16.82	22.75	—	—	75.2	97.5	—	—	2.52	3.19

SUS SAYBOLT	CENTISTOKES	REDWOOD	ENGLER
39	3.88	36	1.30
40	4.20	36.9	1.33

TABLE 2—*Transmission and Axle Lubricants*

SAE VISCOSITY NUMBERS	CENTISTOKES					REDWOOD					ENGLER				
	0 F	100 F		210 F		0 F	100 F		210 F		0 F	100 F		210 F	
	Max	Min	Max	Min	Max	Max	Min	Max	Min	Max	Max	Min	Max	Min	Max
80	21,800	—	—	—	—	86,000	—	—	—	—	2,870	—	—	—	—
90	—	173	324	—	—	—	700	1,300	—	—	—	22.8	42.6	—	—
140	—	—	—	25.1	42.9	—	—	—	107	179	—	—	—	3.47	5.71
250	—	—	—	42.9	—	—	—	—	179	—	—	—	—	5.71	—

Method of Rating Fuels for Detonation

SAE Recommended Practice

Report of Lubricants Division approved January 1931 and last revised by Fuels and Lubricants Technical Committee January 1949.

The performance of spark-ignition internal-combustion engines may be greatly influenced by the antiknock properties of the fuel used. The occurrence of knock or detonation is due to uncontrolled combustion taking place at some time during the burning process and is dependent upon many factors of engine design and operation as well as upon the chemical and physical properties of the fuel. Consequently, fuels which may knock in one engine may not knock in another, and conversely, engines which knock on one fuel may not knock on another. For these reasons, it is extremely difficult to establish an engine test to evaluate the antiknock properties of fuels.

As a result of work initiated in 1927 by the Cooperative Fuel Research Committee (API, AMA, National Bureau of Standards, and SAE), the ASTM has designated two antiknock test methods for motor fuels known currently as the Motor Method (ASTM D 357) and the Research Method (ASTM D 908).[1] The former is a method which measures antiknock performance under relatively severe operating conditions and might be considered indicative of the detonating tendency of a fuel at relatively high engine speeds; the latter under relatively mild operating conditions, and might be considered indicative of the detonating tendency of a fuel at relatively low engine speeds. Both designations give results in terms of blends of 2, 2, 4 trimethyl pentane (100 octane number by definition) and normal heptane (0 octane number by definition) on a linear percentage scale of octane numbers. The octane number of a gasoline is the octane number of a mixture of iso-octane and normal heptane which it matches in antiknock value.

The motor and research octane numbers of a fuel may be close together or may be quite widely separated, depending upon fuel structure; and this spread or difference is commonly referred to as its sensitivity. At the present time there is no completely satisfactory way of translating the motor-method and research-method ratings of a fuel into terms of a road rating for vehicles, but careful consideration of the level of the two numbers and their sensitivity will provide valuable clues as to relative probable performance.

[1] For complete information on methods of test, see ASTM Standards on Petroleum Products and Lubricants, procurable from the American Society for Testing Materials, 1916 Race Street, Philadelphia 2, Pa.

Felts

SAE Standard

Report of Parts and Fittings Division approved July 1923 and last revised by Nonmetallic Materials Technical Committee October 1946.

[*This SAE Standard covers types and qualities of felts required for general automotive uses. It was developed with the cooperation of the Standardization Committee of the Felt Association, Inc. and in accordance with the ASTM tests indicated in the Standard. The included notes and recommended uses are intended as a guide in the selection of felts for more particular uses, but the requirements for each application should be taken into consideration in making final selections.*]

Felt is a fabric built up by the interlocking of fibers by a suitable combination of mechanical work, chemical action, moisture, and heat, without spinning, weaving, or knitting. Felt may consist of one or more classes of fibers, wool, reprocessed wool, and reused wool, with or without admixture with animal, vegetable, and synthetic fibers.[1]

Felt as defined here is commonly referred to as wool felt and does not include punched, woven, synthetically bonded, stitched, quilted, paper, or other materials of felt-like appearance which are products of entirely different constructions and properties.

Clip wools or noils, which are the short-fiber combings resulting from the preparation of wool for spinning, as well as reprocessed and reused wools are used in the manufacture of automotive felts. The best grades of wool are white and are used without admixture with other fibers in the highest grade felts.

Varying amounts of cotton, artificial silk, and other fibers may be used as a filler to reduce the cost of the felt or to impart certain desired characteristics to the finished material. Traces of cotton are found in most commercial "all-wool" felts.

Raw wool contains "wool fat" and "wool perspiration" in addition to mechanically adhering impurities and foreign matter. The foreign matter and some of the wool fat is removed in the scouring operation. Oils and soaps are added in the fabricating process to obtain the necessary degree of felting. Sizing or filler may be used in some of the lower-grade felts and in special applications to stiffen or strengthen the finished material. Adhesives and impregnating materials may be used in special purpose felts to impart specific properties.

The carbon tetrachloride soluble, water soluble, and ash determinations indicate the cleanliness of the fiber and the amount of fats, oils, and sizing materials present in the finished product.

Felts used for ball and roller bearing oil-retaining washers shall be sheared on both sides to give a smooth surface free from "surface fuzz" or "flock."

The quality, appearance, and oil-absorption characteristics may be specified by the purchaser to be in accord with approved samples.

[1] The terms wool, reprocessed wool, and reused wool are defined essentially in accordance with the Wool Products Labelling Act, 1939, as follows:

Wool—The term "wool" means the fiber from the fleece of the sheep or lamb, or hair of the angora or cashmere goat (and may include the so-called specialty fibers from the hair of the camel, alpaca, llama, and vicuna) which has never been reclaimed from any woven or felted wool product.

Reprocessed Wool—The term "reprocessed wool" means the resulting fiber when wool has been woven or felted into a wool product which, without ever having been utilized in any way by the ultimate consumer, subsequently has been made into a fibrous state.

Reused Wool—The term "reused wool" means the resulting fiber when wool or reprocessed wool has been spun, woven, knitted, or felted into a wool product which, after having been used in any way be the ultimate consumer, subsequently has been made into a fibrous state

The commercial trade designations of the more commonly used grades of automotive felts are given in Table 1 along with complete specifications and tolerances for thickness, weight, wool content, chemical and physical requirements, color, and width.

The weight or density requirements for the several grades of automotive felts given in the table are expressed as the weight in pounds per square yard for each commercial thickness. This is the established standard unit of weight employed in the felt industry. Density may also be expressed as the weight in ounces per cubic inch, specific gravity as compared with water, percentage specific gravity (specific gravity × 100), or as surface density in pounds per square yard of nominal 1-in. thickness.

The weight or density of cut parts may be expressed as the weight per one hundred (100) parts based on the nominal weight of the felt in the thickness specified.

The thickness tolerances for the several grades of automotive felt given in Table 1 vary, depending on the density, thickness, and grade or quality of the felt, and are expressed as the permissible minimum and maximum thickness for each grade and thickness rather than as a percentage variation from the nominal thickness.

The chemical and physical requirements for the several grades of automotive felts given in the table include actual wool content (chemical basis), carbon tetrachloride soluble (percentage of residual oil and grease), water soluble (sizing and nonfibrous impurities), ash (the amount of residual inorganic matter), tensile strength, and splitting resistance.

All tests shall be made in accordance with the Standard Methods of Testing Wool Felt, ASTM D 461. If it is desired to detect the presence of, and identify, fibers other than wool, such as other animal fibers, vegetable, and synthetic fibers, the felt shall be subjected to a microscopic examination as described in Tentative Methods of Quantitative Analysis of Textiles, ASTM D 629.

Special sizing, adhesives, and impregnating materials used to impart specific properties may alter the chemical and physical requirements specified in Table 1. The specific properties and methods of test for special products shall be agreed upon by supplier and purchaser.

All density or weight determination shall be based on the thickness of the felt as ordered and no correction shall be made for variations in the thickness of the felt as received. For example, SAE F-1, back-check felt, in ½-in. thickness may, according to the table, vary in weight from 7.60 to 8.40 lb per sq yd, while the thickness may, according to the table, vary from 0.481 to 0.519 in. The combination of weight and thickness tolerances control the degree of felting or matting of the fibers, in other words, the hardness or the density, and conversely, the resiliency of the finished felt. Therefore, to maintain the normal density for each grade or type of felt, no correction in weight is permitted to compensate for a variation from the nominal thickness as specified.

Recommended Uses—SAE F-1 is suitable for oil retention in

(*Text continued after Table 1.*)

TABLE 1—*Standard Mechanical Roll Felt Specifications*

SAE No.	THICKNESS[a], IN.		WEIGHTS,[a] LB PER SQ YD		MINIMUM ACTUAL WOOL CONTENT,[b] %	MAXIMUM CARBON TETRACHLORIDE SOLUBLE, %	MAXIMUM WATER SOLUBLE, %	MAXIMUM COMBINED CARBON TETRACHLORIDE AND WATER, %	MAXIMUM ASH,[c] %	MINIMUM TENSILE STRENGTH, PSI	MINIMUM SPLITTING RESISTANCE,[d] LB. PER 2-IN. WIDTH	TRADE DESIGNATION	COLOR	STANDARD WIDTH, IN.
	Nominal	Limits	Nominal	Limits										
F-1[e]	1/8	0.113–0.137	2.0	1.90– 2.10	95	2.5	2.5	3.0	1.5	500	33	Back check	White	60
	3/16	0.175–0.201	3.0	2.85– 3.15										
	1/4	0.236–0.264	4.0	3.80– 4.20										
	5/16	0.298–0.328	5.0	4.75– 5.25										
	3/8	0.359–0.391	6.0	5.70– 6.30										
	1/2	0.481–0.519	8.0	7.60– 8.40										
	5/8	0.603–0.647	10.0	9.50–10.50										
	3/4	0.725–0.775	12.0	11.40–12.60										
	7/8	0.847–0.903	14.0	13.30–14.70										
	1	0.969–1.031	16.0	15.20–16.80										
F-2	1/8	0.113–0.137	2.0	1.90– 2.10	95	2.5	2.5	4.0	2.0	500	28[g]	Back check	Any color except grey or black	60
	3/16	0.175–0.201	3.0	2.85– 3.15										
	1/4	0.236–0.264	4.0	3.80– 4.20										
	5/16	0.298–0.328	5.0	4.75– 5.25										
	3/8	0.359–0.391	6.0	5.70– 6.30										
	1/2	0.481–0.519	8.0	7.60– 8.40										
	5/8	0.603–0.647	10.0	9.50–10.50										
	3/4	0.725–0.775	12.0	11.40–12.60										
	7/8	0.847–0.903	14.0	13.30–14.70										
	1	0.969–1.031	16.0	15.20–16.80										
F-3[e]	1/8	0.113–0.137	1.95	1.80– 2.10	90	2.5	3.0	4.5	2.5	400	22[g]	Back check	Grey	60
	3/16	0.175–0.201	2.93	2.71– 3.15										
	1/4	0.236–0.264	3.90	3.61– 4.19										
	5/16	0.298–0.328	4.87	4.50– 5.24										
	3/8	0.359–0.391	5.85	5.41– 6.29										
	1/2	0.481–0.519	7.80	7.21– 8.39										
	5/8	0.603–0.647	9.75	9.01–10.49										
	3/4	0.725–0.775	11.70	10.81–12.59										
	7/8	0.847–0.903	13.65	12.61–14.69										
	1	0.969–1.031	15.60	14.41–16.79										
F-5	1/8	0.111–0.139	1.53	1.45– 1.61	95	2.5	2.5	3.0	2.0	400	18	Extra-firm pad	White	60
	3/16	0.172–0.204	2.29	2.17– 2.41										
	1/4	0.232–0.268	3.06	2.90– 3.22										
	5/16	0.293–0.333	3.82	3.62– 4.02										
	3/8	0.353–0.397	4.59	4.35– 4.83										
	1/2	0.474–0.526	6.12	5.80– 6.44										
	5/8	0.595–0.655	7.65	7.25– 8.05										
	3/4	0.716–0.784	9.18	8.70– 9.66										
	7/8	0.837–0.913	10.71	10.15–11.27										
	1	0.958–1.042	12.24	11.60–12.88										
F-6	1/8	0.111–0.139	1.53	1.45– 1.61	92	2.5	2.5	4.5	2.5	275	16	Extra-firm pad	Grey	60 or 72
	3/16	0.172–0.204	2.29	2.17– 2.41										
	1/4	0.232–0.268	3.06	2.90– 3.22										
	5/16	0.293–0.333	3.82	3.62– 4.02										
	3/8	0.353–0.397	4.59	4.35– 4.83										
	1/2	0.474–0.526	6.12	5.80– 6.44										
	5/8	0.595–0.655	7.65	7.25– 8.05										
	3/4	0.716–0.784	9.18	8.70– 9.66										
	7/8	0.837–0.913	10.71	10.15–11.27										
	1	0.958–1.042	12.24	11.60–12.88										

(*Continued on next page.*)

TABLE 1—*Standard Mechanical Roll Felt Specifications (Continued)*

SAE No.	THICKNESS,[a] IN.		WEIGHTS,[a] LB PER SQ YD		MINIMUM ACTUAL WOOL CONTENT,[b] %	MAXIMUM CARBON TETRACHLORIDE SOLUBLE, %	MAXIMUM WATER SOLUBLE, %	MAXIMUM COMBINED CARBON TETRACHLORIDE AND WATER, %	MAXIMUM ASH,[c] %	MINIMUM TENSILE STRENGTH, PSI	MINIMUM SPLITTING RESISTANCE,[d] LB PER 2-IN. WIDTH	TRADE DESIGNATION	COLOR	STANDARD WIDTH, IN.
	Nominal	Limits	Nominal	Limits										
F-7[e]	1/8	0.111–0.139	1.53	1.45– 1.61	80	3.0	4.0	7.0	3.0	250	12	Extra-firm pad	Grey	72
	3/16	0.172–0.204	2.29	2.17– 2.41										
	1/4	0.232–0.268	3.06	2.90– 3.22										
	5/16	0.293–0.333	3.82	3.62– 4.02										
	3/8	0.353–0.397	4.59	4.35– 4.83										
	1/2	0.474–0.526	6.12	5.80– 6.44										
	5/8	0.595–0.655	7.65	7.25– 8.05										
	3/4	0.716–0.784	9.18	8.70– 9.66										
	7/8	0.837–0.913	10.71	10.15–11.27										
	1	0.958–1.042	12.24	11.60–12.88										
F-10	1/8	0.105–0.145	1.06	0.98–1.14	95	2.5	2.5	3.0	2.5	225	8	Firm pad	White	72
	3/16	0.165–0.211	1.59	1.47–1.71										
	1/4	0.224–0.276	2.12	1.96–2.28										
	5/16	0.284–0.342	2.65	2.45–2.85										
	3/8	0.343–0.407	3.18	2.94–3.42										
	1/2	0.462–0.538	4.24	3.92–4.56										
	5/8	0.581–0.669	5.30	4.90–5.70										
	3/4	0.700–0.800	6.36	5.88–6.84										
	7/8	0.819–0.931	7.42	6.86–7.98										
	1	0.938–1.062	8.48	7.84–9.12										
F-11	1/8	0.105–0.145	1.06	0.98–1.14	92	3.0	2.5	4.5	3.0	200	6	Firm pad	Grey	72
	3/16	0.165–0.211	1.59	1.47–1.71										
	1/4	0.224–0.276	2.12	1.96–2.28										
	5/16	0.284–0.342	2.65	2.45–2.85										
	3/8	0.343–0.407	3.18	2.94–3.42										
	1/2	0.462–0.538	4.24	3.92–4.56										
	5/8	0.581–0.669	5.30	4.90–5.70										
	3/4	0.700–0.800	6.36	5.88–6.84										
	7/8	0.819–0.931	7.42	6.86–7.98										
	1	0.938–1.062	8.48	7.84–9.12										
F-12	1/8	0.105–0.145	1.06	0.98–1.14	85	4.0	2.5	6.5	3.5	100	3	Firm pad	Grey	72
	3/16	0.165–0.211	1.59	1.47–1.71										
	1/4	0.224–0.276	2.12	1.96–2.28										
	5/16	0.284–0.342	2.65	2.45–2.85										
	3/8	0.343–0.407	3.18	2.94–3.42										
	1/2	0.462–0.538	4.24	3.92–4.56										
	5/8	0.581–0.669	5.30	4.90–5.70										
	3/4	0.700–0.800	6.36	5.88–6.84										
	7/8	0.819–0.931	7.42	6.86–7.98										
	1	0.938–1.062	8.48	7.84–9.12										
F-13	1/8	0.105–0.145	1.06	0.98–1.14	75	4.0	4.0	8.0	3.5	75	2	Firm pad	Grey	72
	3/16	0.165–0.211	1.59	1.47–1.71										
	1/4	0.224–0.276	2.12	1.96–2.28										
	5/16	0.284–0.342	2.65	2.45–2.85										
	3/8	0.343–0.407	3.18	2.94–3.42										
	1/2	0.462–0.538	4.24	3.92–4.56										
	5/8	0.581–0.669	5.30	4.90–5.70										
	3/4	0.700–0.800	6.36	5.88–6.84										
	7/8	0.819–0.931	7.42	6.86–7.98										
	1	0.938–1.062	8.48	7.84–9.12										

(*Continued on next page.*)

TABLE 1—*Standard Mechanical Roll Felt Specifications (Concluded)*

SAE No.	Thickness,[a] in.		Weights,[a] lb per sq. yd		Minimum Actual Wool Content,[b] %	Maximum Carbon Tetrachloride Soluble, %	Maximum Water Soluble, %	Maximum Combined Carbon Tetrachloride and Water, %	Maximum Ash,[c] %	Minimum Tensile Strength, psi	Minimum Splitting Resistance,[d] lb per 2-in. width	Trade Designation	Color	Standard Width, in.
	Nominal	Limits	Nominal	Limits										
F-15	1/8	0.105–0.145	1.06	0.98–1.14	55	4.0	5.0	9.0	4.0	75	2	Firm pad	Grey	72
	3/16	0.165–0.211	1.59	1.47–1.71										
	1/4	0.224–0.276	2.12	1.96–2.28										
	5/16	0.284–0.342	2.65	2.45–2.85										
	3/8	0.343–0.407	3.18	2.94–3.42										
	1/2	0.462–0.538	4.24	3.92–4.56										
	5/8	0.581–0.669	5.30	4.90–5.70										
	3/4	0.700–0.800	6.36	5.88–6.84										
	7/8	0.819–0.931	7.42	6.86–7.98										
	1	0.938–1.062	8.48	7.84–9.12										
F-26	1/8	0.085–0.165	0.90	0.81–0.99	45	8.0	6.0	14.0	5.0	—	—	Soft pad	Grey	72
	1/4	0.194–0.306	1.80	1.62–1.98										
	3/8	0.303–0.447	2.70	2.43–2.97										
	1/2	0.412–0.588	3.60	3.24–3.96										
	3/4	0.630–0.870	5.40	4.86–5.94										
	1	0.848–1.152	7.20	6.48–7.92										
F-50[f]	3/64	0.040–0.054	0.750	0.712–0.788	95	2.5	2.5	3.0	1.5	500	—	Ball-bearing felt	White	60 or 72
	1/16	0.056–0.070	0.975	0.937–1.013										
	5/64	0.071–0.085	1.200	1.162–1.238										
	3/32	0.087–0.101	1.425	1.387–1.463										
F-51[f]	3/64	0.040–0.054	0.750	0.712–0.788	92	2.5	2.5	4.5	2.5	300	—	Ball-bearing felt	Grey	60 or 72
	1/16	0.056–0.070	0.975	0.937–1.013										
	5/64	0.071–0.085	1.200	1.162–1.238										
	3/32	0.087–0.101	1.425	1.387–1.463										
F-55[f]	1/16	0.056–0.070	0.750	0.712–0.788	75	4.0	4.0	8.0	3.0	200	—	Lining	Grey or black	60 or 72
	3/32	0.087–0.101	1.125	1.087–1.163										

[a] Nominal weights of SAE F-10, F-11, F-12, F-13, F-15, and F-26 have been given minor adjustments to provide uniform weight increments for unit thickness. Weight tolerances of F-7 have been made the same as F-5 and F-6, and those of F-10 the same as F-11, F-12, F-13, and F-15 with minor tolerance changes in the latter group as required for uniformity. Thickness tolerances for all grades have been slightly adjusted for uniformity and narrowed in accordance with manufacturing practice on thicknesses above ½ in.

[b] The actual wool content indicates the per cent of wool by chemical analysis and is exclusive of traces of other fibers and impurities present in the wool used in fabricating the several grades of felt. For example, SAE F-1, fabricated from 100% wool, may contain incidental traces of cotton and other fibers, residual wool fats, and oils or soaps used in processing which may reduce the actual wool fiber content on analysis to a minimum of 95%.

[c] Maximum ash residue has been increased for all qualities except SAE F-15, F-26, and F-55.

[d] Splitting resistance is not applicable to felts where the thickness is less than 3/16 in. For materials less than 3/16 in. in thickness, breaking strength only is recommended as an indicative test.

[e] For thicknesses less than ¼ in., for SAE F-1, see SAE F-50; F-3, see SAE F-51; F-7, see SAE F-55.

[f] The former eight thicknesses for SAE F-50, F-51, and F-55 have been replaced by four thicknesses for F-50 and F-51 and two thicknesses for F-55, as tabulated; weights have been expressed in lb per sq yd to conform with other grades.

[g] Splitting resistance of SAE F-3 reduced from 24 to 22 lb per 2-in. width, and of SAE F-2 form 30 to 28 lb per 2-in. width.

installations where the felt is not compressed, for feeding low viscosity or light oil, and where unusual strength and hardness are required. Washers, bushings, wicks, door bumpers, polishing blocks, and parts where wear and resistance to abrasion are required are typical uses.

SAE F-2 and F-3 are recommended for vibration mountings and the same general purposes as SAE F-1 and where a felt of slightly lower quality is satisfactory.

SAE F-5, F-6, and F-7 are recommended for dust shields, wipers, grease-retainer washers, wicks, vibration mountings, and in uses where a resilient felt is required.

SAE F-10, F-11, and F-12 are recommended for grease and oil retention where the felt is confined and compressed in assembly. Also recommended for dust shields under less severe operating conditions where F-5, F-6, and F-7 are not required.

SAE F-13 and F-15 are recommended for sound deadening, chassis strips, spacers, dust shields, pedal pads, dash liners, and for mechanical purposes where abrasion and wear are not important factors.

SAE F-26 is suitable for packing or padding when held in place between other materials. This grade should not be used for mechanical purposes.

SAE F-1 to F-26 inclusive can be obtained in thicknesses up to 1 in. The weight and thickness tolerances shall be agreed upon by supplier and purchaser.

SAE F-50 is recommended for ball and roller bearing oil-retainer washers and small dust-excluding washers; also for mechanical purposes where an accurate, thin, smooth, high-grade felt is required.

SAE F-51 is recommended for the same general uses as F-50 but in installations where tolerances and length of life are not as important; also for thin cut parts such as gaskets and liners.

SAE F-55 is recommended for antisqueak strips and for lining when cemented to fiber board or metal panels.

Screw Threads

SAE Standard

SAE Regular (NF Series) approved June 1911; SAE Fine (NEF Series) approved January 1915; SAE Special-Pitch Series approved June 1926; Coarse (NC Series) approved January 1935; 8, 12, and 16 (National Series) approved January 1935. Last revisions by Screw Threads Technical Committee January 1951. This SAE Standard conforms in general with American Standard Unified and American Screw Threads, ASA B1. 1-1949.

[*This SAE Standard differs from the Unified and American Standard B1.1-1949 (Second Edition, December 1949) in that the SAE Standard contains a table, Table 2, giving the standard series of diameter-pitch combinations, and in that Tables 3, 5, 7, 9, 11, and 13 (allowances and tolerances) of B1.1-1949 are omitted because the data in these tables are included in other tables of both published standards (SAE Tables 9 to 20). Drawings, formulas, and definitions correspond throughout both published standards.*]

Corresponding Tables

SAE STANDARD	B1.1-1949	SAE STANDARD	B1.1-1949
1	1	17a to 17f	22
2	—	18a to 18f	23
3	2	19a to 19f	24
	3	20a to 20f	25
4	4	21	25A
	5	22	26
5	6	23	27
	7	24	28
6	8	25	29
	9	26	30
7	10	27	31
	11	28	32
8	12	29	33
	13	30	34
9	14	31a, 31b	35
10a, 10b	15	32a, 32b	36
11	16	33	37
12	17	34	38
13a, 13b	18	35	39
14	19	36	40
15a, 15b	20	37a to 37g	41
16a, 16b	21		

Section 1—Introduction

1. There is no end to the development and improvement of an active standard. This revised edition of American Standard B1.1 and the SAE Standard marks an important step forward in that they embody the Unified thread standards which have been agreed upon by standardization committees of Canada, the United Kingdom, and the United States and signalized by the signing of an Accord at Washington, D. C. on November 18, 1948. These Unified standards constitute the basic American standards. The earlier American standards are, in part, continued in this Standard.

This Standard incorporates a number of changes resulting from practical experience in manufacture, assembly, and use. World War II saw many of them tried and proved. Of particular interest are:

a—Maximum metal-thread contours which provide for greater fatigue strength, root clearance, easier assembly, and longer wear of cutting tools. The clearances allowed are such as to permit rounded root form in both the external and internal threads. Rounded roots are required in some applications and are made by tools that are purposely rounded. Otherwise, round roots may be the result of tool wear.

b—Class 2A tolerances and allowances for external threads computed by formula, which provide a clearance under all conditions.

c—Class 2B tolerances for internal threads, computed by formula.

d—New classes of tolerances designated 1A for external threads and 1B for internal threads, intended to replace the old Class 1 for new work, which are formulated according to the principles of the Class 2A and Class 2B tolerances and allowances. The tolerances on Classes 1A and 1B are 1.5 times those on Classes 2A and 2B, respectively, and the allowance on 1A is the same as that on 2A.

e—New classes of tolerances, 3A for external and 3B for internal threads, which also are in accord with the principles and formulas of the 2A and 2B classes of tolerances. The tolerances on 3A and 3B are 0.75 times those allowed on 2A and 2B, respectively, but no allowance is provided on 3A. These classes of tolerance are less liberal than 2A and 2B.

f—Classes 2 and 3 have been retained without change, but they are not among the Unified classes. The thread forms, however, are identical.

g—Class 4 has been dropped. It has been used rather seldom and almost invariably to meet particular requirements.

h—Interference fits are now the subject of active study and will be contained in a separate standard as soon as details are developed.

i—The ½ in.—13 NC size has been listed as alternate to the ½ in.—12 UNC size.

j—12 threads per in. have been made standard for 1 in.—UNF threads, but the 1 in.—14 NF thread is included in the tables.

k—Classes of threads are distinguished by the amount of manufacturing tolerances and allowances (if any) permissible for externally or internally threaded components. Various fits of thread assemblies can be obtained by combining suitable classes of threads.

2. Several appendices present useful information supplementary to this standard.

a—For definition of terms and symbols used in the text,

see Appendix A; and for formulas from which values in tables were derived, see Appendices B, C, D, and E.

b—Appendix G gives tables for the old Class 1.

Section 2—Thread Form and Formulas Unified and American

See Fig. 1 for thread form, Fig. 4 for dimension symbols, and Table 1 for values.

Angle of thread: $2a = 60°$

Half angle of thread: $a = 30°$

Number of threads per inch: $n = \frac{1}{p}$

Pitch of thread: $p = \frac{1}{n}$

Height of sharp V thread: $H = 0.86603p = \frac{0.86603}{n}$

[1]Height of external thread: $h_s = 0.61343p = \frac{0.61343}{n} = \frac{17}{24}H$

Height of internal thread: $h_n = 0.54127p = \frac{0.54127}{n} = \frac{5}{8}H$

Depth of thread engagement: $h_e = 0.54127p = \frac{0.54127}{n}$

Flat at crest of external thread: $F_{cs} = 0.125p = \frac{0.125}{n} = \frac{p}{8}$

Truncation of external-thread crest: $f_{cs} = 0.10825p = \frac{0.10825}{n} = \frac{H}{8}$

[1]Truncation of external-thread rounded root: $s_{rs} = 0.14434p = \frac{0.14434}{n} = \frac{H}{6}$

Flat at crest of internal thread: $F_{cn} = 0.25p = \frac{0.25}{n} = \frac{p}{4}$

Truncation of internal-thread crest: $f_{cn} = 0.21651p = \frac{0.21651}{n} = \frac{H}{4}$

Flat at root of internal thread: $F_{rn} = 0.125p = \frac{0.125}{n} = \frac{p}{8}$

Truncation of internal-thread root: $f_{rn} = 0.10825p = \frac{0.10825}{n} = \frac{H}{8}$

Addendum of external thread: $h_{as} = 0.32476p = \frac{0.32476}{n} = \frac{3}{8}H$

[2]Major diameter of external thread (nominal diameter): D_s

[2,3]Pitch diameter of external thread: $E_s = D - 2h_{as} = D - 0.64952p = D - \frac{0.64952}{n}$

Minor diameter of external thread: $K_s = D_s - 2h_s = D_s - 1.22687p = D_s - \frac{1.22687}{n}$

[2]Major diameter of internal thread: D_n

[2]Pitch diameter of internal thread: E_n

Minor diameter of internal thread: $K_n = D_n - 2h_n = D_n - 1.08253p = D_n - \frac{1.08253}{n}$

[1] For calculating minor-diameter and stress-area values in tables.

[2] Because external and internal threads have the same basic major diameters and the same basic pitch diameters, the subscripts are omitted from D and E in subsequent references to these diameters.

[3] $2h_{as} = h_b$ = the basic height, h, of the original American National form.

[4] Where a designation of a screw thread starts with U, it indicates that this series or diameter-pitch combination corresponds in all respects (including tolerances and allowances) with the British and Canadian thread of the same designation. However, where the U does not appear in a thread designation of Classes 1A, 2A, 3A, 1B, 2B, or 3B, all thread elements conform to the principles on which Unified threads are based.

Section 3—Thread Series and Suggested Applications

3. Series of threads are classified and distinguished from each other by the number of threads per inch applied to a specific diameter. The Unified Screw Threads[4] are limited to the coarse- and fine-thread series of Classes 1A, 1B, 2A, 2B, 3A, and 3B as indicated in the tables of numerical values and preferred selected combinations of special threads of Classes 2A and 2B.

4. Wherever possible, a Unified or American thread of the coarse- or fine-thread series should be used. If no such thread meets the requirements of the design, it is important to refer to the various tables in proper sequence. After looking for the required thread in the tables of limits of size for the standard

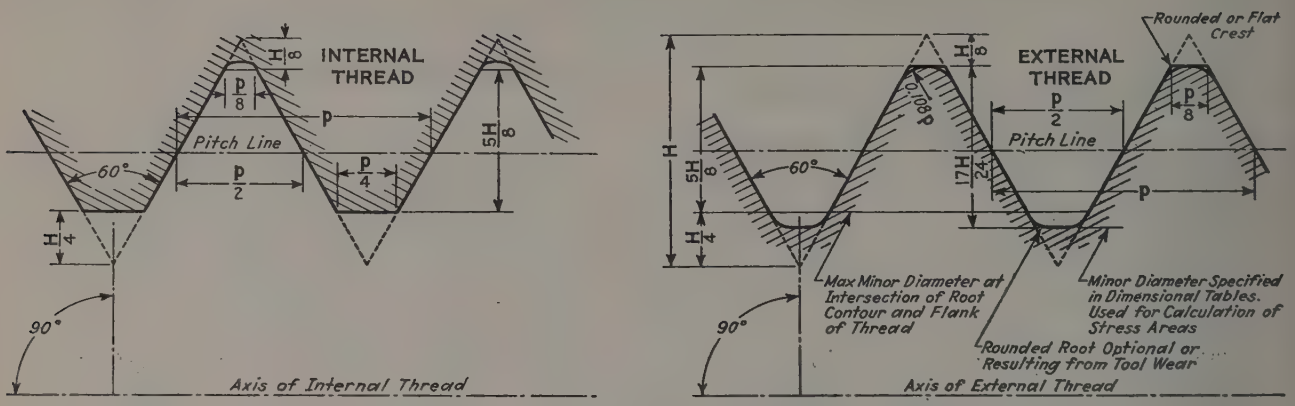


FIG. 1—UNIFIED AND AMERICAN INTERNAL AND EXTERNAL THREAD DESIGN FORMS. (MAXIMUM METAL CONDITION)

series, reference is made to the tables of limits of size for selected combinations of special diameter and pitch. Reference is made to the step tables as the third expedient. Calculation of thread values by formula is the last resort.

5. **Coarse-Thread Series** (SAE Tables 3, 9, to 16)

The Coarse-Thread Series, designated as shown in the tables, is the former United States Standard supplemented in the sizes below ¼ in. by a part of the Standard Proportions for Machine Screws established by the American Society of Mechanical Engineers in 1907 (ASME Transactions 1907, No. 1142). It is recommended for general use in engineering work where conditions do not require the use of a fine thread.

Basic dimensions for the Unified and American National Coarse-Thread Series are given in SAE Table 3. Limits of size, based on a length of engagement equal to the nominal diameter, are given in SAE Tables 9 to 16, inclusive, for Classes 1A, 2A, 3A, 1B, 2B, 3B, 2, and 3.

6. **Fine-Thread Series** (SAE Tables 4, 9 to 16)

The Fine-Thread Series, designated as shown in the tables, is the former Regular Screw-Thread Series established by the Society of Automotive Engineers in 1911 and supplemented below ¼ in. by sizes of the Standard Proportions for Machine Screws established by the American Society of Mechanical Engineers. It is recommended for general use in automotive and aircraft work and where special conditions require a fine thread.

Basic dimensions for the Unified and American Fine-Thread Series are given in SAE Table 4. Limits of size, based on a length of engagement equal to the nominal diameter, are given in SAE Tables 9 to 16, inclusive, for Classes 1A, 2A, 3A, 1B, 2B, 3B, 2, and 3.

7. **Extra-Fine Thread Series** (SAE Tables 5, 17 to 20)

The Extra-Fine Thread Series, designated UNEF or NEF as shown in the tables of selected combinations of Section 5—Special Threads, is the same as the former SAE Fine Series and the present SAE Extra-Fine Series. It is used particularly in aircraft and aeronautical equipment where thin-walled material is to be threaded; thread depth of nuts clearing ferrules, coupling flanges, or the like must be held to a minimum; and a maximum practicable number of threads is required within a given thread length.

Basic dimensions for the American Extra-Fine Series are given in SAE Table 5. Limits of size, based on a length of engagement of 9 pitches for Classes 2A, 2B, 2, and 3 are given in SAE Tables 17 to 20.

8. **8-Thread Series** (SAE Tables 6, 10, 13, 15, and 16)

The 8-Thread Series is designated 8 N. Bolts for high-pressure pipe flanges, cylinder-head studs, and similar fasteners against pressure require that an initial tension be set up by elastic deformations of the fastener and the components held together so that the joint will not open up when the steam or other pressure is applied. To secure a proper initial tension, it is not practicable that the pitch should increase with the diameter of the thread as the torque required to assemble would be excessive. Accordingly, for such purposes, the 8-thread series has come into general use in many classes of engineering work and as a substitute for the coarse-thread series. The 8-thread series is based on a length of engagement equal to the nominal diameter for Classes 2A and 2B; and equal to the nominal diameter for sizes up to and including 3 in.; and 3 in. for larger sizes, for Classes 2 and 3. Basic dimensions are given in SAE Table 6. Limits of size are given in SAE Tables 10, 13, 15, and 16 for Classes 2A, 2B, 2, and 3.

(If a thread is in both the 8-thread series and the coarse-thread series, the symbol and tolerances of the coarse-thread series apply.)

9. **12-Thread Series** (SAE Tables 7, 17, 18, 19, and 20)

The 12-Thread Series is designated 12 UN or 12 N as shown in the tables of selected combinations of Section 5—Special Threads. Sizes of 12-pitch threads from ½ in. to and including 1¾ in. are used in boiler practice. This requires that worn stud holes be retapped with a tap of the next larger size, the increment being 1/16 in. throughout most of the range. The 12-thread series is also widely used in machine construction for thin nuts on shafts and sleeves. From the standpoint of good design and

TABLE 1—*Thread Data, Unified and American Thread Form*

THREADS PER INCH, n	PITCH, p	HEIGHT OF SHARP-V THREAD, $H = 0.86603p$	HEIGHT OF EXTERNAL THREAD, $h_s = 17/24H = 0.61343p$	HEIGHT OF INTERNAL THREAD, $h_n = 5/8H = 0.54127p$	DEPTH OF THREAD ENGAGEMENT, $h_e = 5/8H = 0.54127p$	FLAT AT EXTERNAL-THREAD CREST, $F_{cs} = p/8 = 0.125p$	TRUNCATION OF EXTERNAL-THREAD CREST, $f_{cs} = H/8 = 0.10825p$	TRUNCATION OF EXTERNAL-THREAD ROOT, $s_{rs} = H/6 = 0.14434p$	FLAT AT INTERNAL-THREAD CREST, $F_{cn} = p/4 = 0.25p$	TRUNCATION OF INTERNAL-THREAD CREST, $f_{cn} = H/4 = 0.21651p$	FLAT AT INTERNAL-THREAD ROOT, $F_{rn} = p/8 = 0.125p$	TRUNCATION OF INTERNAL-THREAD ROOT, $f_{rn} = H/8 = 0.10825p$	ADDENDUM OF EXTERNAL THREAD, $h_{as} = 3/8H = 0.32476p$	TWICE THE EXTERNAL-THREAD ADDENDUM,[a] $h_b = 2h_{as} = 3/4H = 0.64952p$
80	0.01250	0.01083	0.00767	0.00677	0.00677	0.00156	0.00135	0.00180	0.00312	0.00271	0.00156	0.00135	0.00406	0.00812
72	0.01389	0.01203	0.00852	0.00752	0.00752	0.00174	0.00150	0.00200	0.00347	0.00301	0.00174	0.00150	0.00451	0.00902
64	0.01563	0.01353	0.00958	0.00846	0.00846	0.00195	0.00169	0.00226	0.00391	0.00338	0.00195	0.00169	0.00507	0.01015
56	0.01786	0.01546	0.01095	0.00967	0.00967	0.00223	0.00193	0.00258	0.00446	0.00387	0.00223	0.00193	0.00580	0.01160
48	0.02083	0.01804	0.01278	0.01128	0.01128	0.00260	0.00226	0.00301	0.00521	0.00451	0.00260	0.00226	0.00677	0.01353
44	0.02273	0.01968	0.01394	0.01230	0.01230	0.00284	0.00246	0.00328	0.00568	0.00492	0.00284	0.00246	0.00738	0.01476
40	0.02500	0.02165	0.01534	0.01353	0.01353	0.00312	0.00271	0.00361	0.00625	0.00541	0.00312	0.00271	0.00812	0.01624
36	0.02778	0.02406	0.01704	0.01504	0.01504	0.00347	0.00301	0.00401	0.00694	0.00601	0.00347	0.00301	0.00902	0.01804
32	0.03125	0.02706	0.01917	0.01691	0.01691	0.00391	0.00338	0.00451	0.00781	0.00677	0.00391	0.00338	0.01015	0.02030
28	0.03571	0.03093	0.02191	0.01933	0.01933	0.00446	0.00387	0.00515	0.00893	0.00773	0.00446	0.00387	0.01160	0.02320
24	0.04167	0.03608	0.02556	0.02255	0.02255	0.00521	0.00451	0.00601	0.01042	0.00902	0.00521	0.00451	0.01353	0.02706
20	0.05000	0.04330	0.03067	0.02706	0.02706	0.00625	0.00541	0.00722	0.01250	0.01083	0.00625	0.00541	0.01624	0.03248
18	0.05556	0.04811	0.03408	0.03007	0.03007	0.00694	0.00601	0.00802	0.01389	0.01203	0.00694	0.00601	0.01804	0.03608
16	0.06250	0.05413	0.03834	0.03383	0.03383	0.00781	0.00677	0.00902	0.01562	0.01353	0.00781	0.00677	0.02030	0.04059
14	0.07143	0.06186	0.04382	0.03866	0.03866	0.00893	0.00773	0.01031	0.01786	0.01546	0.00893	0.00773	0.02320	0.04639
13	0.07692	0.06662	0.04719	0.04164	0.04164	0.00962	0.00833	0.01110	0.01923	0.01665	0.00962	0.00833	0.02498	0.04996
12	0.08333	0.07217	0.05112	0.04511	0.04511	0.01042	0.00902	0.01203	0.02083	0.01804	0.01042	0.00902	0.02706	0.05413
11½	0.08696	0.07531	0.05334	0.04707	0.04707	0.01087	0.00941	0.01255	0.02174	0.01883	0.01087	0.00941	0.02824	0.05648
11	0.09091	0.07873	0.05577	0.04921	0.04921	0.01136	0.00984	0.01312	0.02273	0.01968	0.01136	0.00984	0.02952	0.05905
10	0.10000	0.08660	0.06134	0.05413	0.05413	0.01250	0.01083	0.01443	0.02500	0.02165	0.01250	0.01083	0.03248	0.06495
9	0.11111	0.09623	0.06816	0.06014	0.06014	0.01389	0.01203	0.01604	0.02778	0.02406	0.01389	0.01203	0.03608	0.07217
8	0.12500	0.10825	0.07668	0.06766	0.06766	0.01562	0.01353	0.01804	0.03125	0.02706	0.01562	0.01353	0.04059	0.08119
7	0.14286	0.12372	0.08763	0.07732	0.07732	0.01786	0.01546	0.02062	0.03571	0.03093	0.01786	0.01546	0.04639	0.09279
6	0.16667	0.14434	0.10224	0.09021	0.09021	0.02083	0.01804	0.02406	0.04167	0.03608	0.02083	0.01804	0.05413	0.10825
5	0.20000	0.17321	0.12269	0.10825	0.10825	0.02500	0.02165	0.02887	0.05000	0.04330	0.02500	0.02165	0.06495	0.12990
4½	0.22222	0.19245	0.13632	0.12028	0.12028	0.02778	0.02406	0.03208	0.05556	0.04811	0.02778	0.02406	0.07217	0.14434
4	0.25000	0.21651	0.15336	0.13532	0.13532	0.03125	0.02706	0.03608	0.06250	0.05413	0.03125	0.02706	0.08119	0.16238

[a] Equivalent to the basic height, h, of the original American National form. $h_{an} = f_{cn} = H/4$; $h_{dn} = h_{as} = 3/8H$. (See Fig. 4).

simplification of practice, it is desirable to limit shoulder diameters to steps of not less than ⅛ in. The 12 pitch is the coarsest pitch in general use which will permit a threaded collar, which screws onto a threaded shoulder, to slip over a shaft, the difference in diameter between shoulder and shaft being ⅛ in. It also provides continuation of the fine thread series (UNF) for diameters larger than 1½ in.

Basic dimensions for the American 12-Thread Series are given in SAE Table 7. Limits of size, based on a length of engagement equal to 9 pitches for Classes 2A, 2B, 2, and 3 are given in SAE Tables 17, 18, 19, and 20.

(If a thread is in both the 12-thread series and the coarse- or fine-thread series, the symbols and tolerances of the coarse- or fine-thread series apply.)

10. **16-Thread Series** (SAE Tables 8, 17, 18, 19, and 20)

The 16-Thread Series, designated 16 UN or 16 N as shown in the tables of selected combinations of Section 5—Special Threads, is a uniform-pitch series for such applications as require a very fine thread. It is intended for such uses as on threaded adjusting collars and bearing retaining nuts. It also provides continuation of the extra-fine thread series (NEF) for diameters larger than 2 in.

Basic dimensions for the American National 16-Thread Series are given in SAE Table 8. Limits of size, based on a length of engagement equal to 9 pitches for Classes 2A, 2B, 2, and 3 are given in SAE Tables 17, 18, 19, and 20.

(If a thread is in both the 16-thread series and the fine- or extra-fine thread series, the symbols and tolerances of the fine- or extra-fine thread series apply.)

11. **Special Threads**

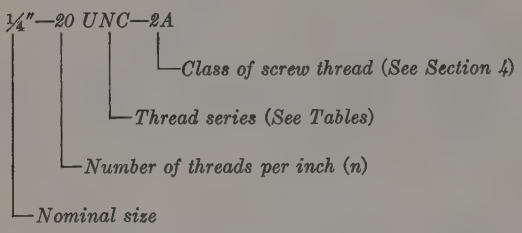
Special threads, designated UN, UNS, or NS as shown in the tables of Section 5—Special Threads, cover non-standard or special combinations of diameter, pitch, and length of engagement.

12. **Method of Designating a Screw Thread**

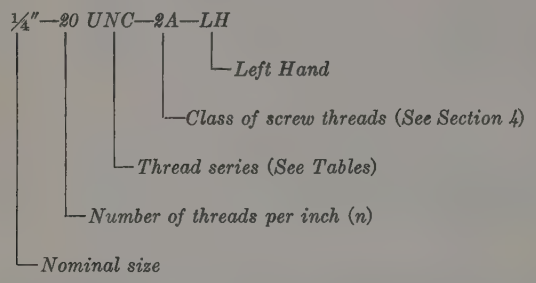
The method of designating a screw thread is by the use of the initial letters of the thread series, preceded by the nominal size (diameter in inches or the screw number) and number of threads

per inch, all in Arabic characters, and followed by the classification designation, with or without the pitch-diameter tolerances or limits of size.

An example of an external-thread designation and its meaning is:



A left-hand thread must be identified by the letters LH following the class designation. If no such designation is used, the thread will be understood to be right hand. An example of a left-hand external-thread designation is:



If a standard thread is modified by the inclusion of some nonstandard feature, such as a smaller major diameter, the word "modified" should be added with an asterisk, and the nonstandard feature or dimension of the thread should be enclosed in brackets and likewise marked with an asterisk.

If a standard thread has a long length of engagement for which standard allowances and tolerances are not applicable, such special length should be noted on the drawing or included in the designation, as for example:

¾"—16 UNF—2A (1 ½ length of engagement)

Tolerances and allowances for the UNF series are calculated for a length of engagement equal to the nominal diameter. When the length of engagement exceeds 1½ times the nominal diameter, tolerances and allowances should be obtained from the Special Thread step Tables 22 to 30, if applicable, or computed from the formulas in Appendices C and E and constants in SAE Table 33. In this example, the tolerance for pitch diameter should be 0.0056 and the allowance, 0.0017 (corresponding to increases of 0.0006 and 0.0002, respectively, over the values for a length of engagement equal to the nominal diameter).

Section 4 —Unified and American Thread Classes

13. **General**

Classes of thread are distinguished from each other by the amounts of tolerance and allowance specified. This Standard includes Classes 1A, 2A, and 3A applied to external threads only; Classes 1B, 2B, and 3B applied to internal threads only; and Classes 2 and 3 applied to both internal and external threads. It is not the purpose of this Standard to limit applications of the various standard classes of tolerances. The requirements for a screw-thread fit for specific applications are predicated on end use and can be met by specifying the proper combination of thread classes for the components. For example, a Class 2A external thread can be used with Classes 1B, 2B, 3B, 2, or 3 internal threads for specific applications.

14. **Classes 1A and 1B** (SAE Tables 9, 12, 22, 23, 26, and 31)

For ordnance and other special uses, Class 1A applied to external threads and Class 1B applied to internal threads replace Class 1 of the former American Standard B1.1—1935 for all new items. Pertinent data for UNC and UNF series for sizes ¼ in. and larger appear in SAE Tables 9 and 12, and step Tables 22, 23, and 26. Items which at present are standardized for production may of necessity remain as at present under the designation of Class 1[5]. Class 1A maximum dimensions are less than basic by the amount of the same allowance as applied to Class 2A (see Paragraph 15) and for the same purpose. Classes 1A and 1B UNC and UNF threads are included as information regarding British practice, being applied to British black bolts. Classes 1A and 1B UNS or NS threads are applied principally to ordnance.

15. **Classes 2A and 2B** (SAE Tables 10, 13, 17, 18, 22, 24, 27, and 31)

Class 2A applied to external threads and Class 2B applied to internal threads are the recognized standards for the normal production of screws, bolts, and nuts. They are also suitable for a wide variety of other applications. Class 2A maximum dimensions are less than basic by the amount of an allowance; the main purpose of this allowance is to provide a minimum clearance between external and internal threads, thus minimizing galling and seizure encountered in assembly and use. An additional advantage of the allowance is that it supplies a space to take care of plating applied to external threads. Where the allowance is not sufficient for thicknesses of plating or coating required, special provisions are necessary.

16. **Classes 3A and 3B** (SAE Tables 11, 14, 25, 28, and 31)

Classes 3A (external threads) and 3B (internal threads) are new classes of tolerances. Class 3A has no allowance; its maximum dimensions are basic.

17. **Classes 2 and 3**[6] (SAE Tables 15, 16, 19, 20, 29, 30, and 32)

Class 2 and Class 3 have been retained. No allowances are provided. Basic dimensions are used for maximum external- and minimum internal-thread dimensions. Tolerances for Class 3 are approximately 70% of Class 2 tolerances.

18. **Pitch-Diameter Tolerances of All Classes**

The tolerances for pitch diameter are cumulative, that is, include the variations of lead and angle. Therefore, the full tolerance is not available for pitch diameter unless the lead and angle of the thread are perfect.

19. **Minor Diameter of Internal Threads**

The minimum minor diameters of internal threads are the same for all classes. The maximum minor diameters are the same for Classes 1B, 2B, and 3B but differ from those for Classes 2 and 3.

20. **Length of Engagement**

The tolerances specified for UNC, UNF, and 8 N series are based on a length of engagement equal to the nominal major diameter of the external thread. For NEF, 12 N, and 16 N series as they appear in SAE Tables 17, 18, 19, and 20 of selected combinations of special threads, the tolerances are based on a length of engagement of 9 pitches.

(Text continued after Table 16b.)

[5] Class 1 step tables appear in Appendix G.
[6] Classes 2 and 3 are not Unified classes.

TABLE 2—*Unified and American Screw-Thread Series*

SIZE	BASIC MAJOR DIAMETER	THREADS PER INCH						SIZE
		Coarse (UNC or NC)	Fine[a] (UNF or NF)	Extra fine[b] (UNEF or NEF)	8-Thread series (N)	12-Thread series (UN or N)	16-Thread series (UN or N)	
0	0.0600	—	80 NF	—	—	—	—	0
1	0.0730	64 NC	72 NF	—	—	—	—	1
2	0.0860	56 NC	64 NF	—	—	—	—	2
3	0.0990	48 NC	56 NF	—	—	—	—	3
4	0.1120	40 NC	48 NF	—	—	—	—	4
5	0.1250	40 NC	44 NF	—	—	—	—	5
6	0.1380	32 NC	40 NF	—	—	—	—	6
8	0.1640	32 NC	36 NF	—	—	—	—	8
10	0.1900	24 NC	32 NF	—	—	—	—	10
12	0.2160	24 NC	28 NF	32 NEF	—	—	—	12
1/4	0.2500	20 [c]	28 [c]	32 NEF	—	—	—	1/4
5/16	0.3125	18 [c]	24 [c]	32 NEF	—	—	—	5/16
3/8	0.3750	16 [c]	24 [c]	32 NEF	—	—	—	3/8
7/16	0.4375	14 [c]	20 [c]	28 [c]	—	—	—	7/16
1/2	0.5000	13 NC	20 [c]	28 [c]	—	12 [c]	—	1/2
1/2	0.5000	12 UNC	—	—	—	—	—	1/2
9/16	0.5625	12 [c]	18 [c]	24 NEF	—	12 [c]	—	9/16
5/8	0.6250	11 [c]	18 [c]	24 NEF	—	12 N	—	5/8
11/16	0.6875	—	—	24 NEF	—	12 N	—	11/16
3/4	0.7500	10 [c]	16 [c]	20 [c]	—	12 N	16 [c]	3/4
13/16	0.8125	—	—	20 [c]	—	12 N	16 [c]	13/16
7/8	0.8750	9 [c]	14 [c]	20 [c]	—	12 N	16 [c]	7/8
15/16	0.9375	—	—	20 [c]	—	12 [c]	16 [c]	15/16
1	1.0000	—	14 NF	—	—	—	—	1
1	1.0000	8 [c]	12 UNF	20 [c]	8 N	12 N	16 [c]	1
1 1/16	1.0625	—	—	18 NEF	—	12 [c]	16 [c]	1 1/16
1 1/8	1.1250	7 [c]	12 [c]	18 NEF	8 N	12 [c]	16 [c]	1 1/8
1 3/16	1.1875	—	—	18 NEF	—	12 [c]	16 [c]	1 3/16
1 1/4	1.2500	7 [c]	12 [c]	18 NEF	8 N	12 [c]	16 [c]	1 1/4
1 5/16	1.3125	—	—	18 NEF	—	12 [c]	16 [c]	1 5/16
1 3/8	1.3750	6 [c]	12 [c]	18 NEF	8 N	12 [c]	16 [c]	1 3/8
1 7/16	1.4375	—	—	18 NEF	—	12 [c]	16 [c]	1 7/16
1 1/2	1.5000	6 [c]	12 [c]	18 NEF	8 N	12 [c]	16 [c]	1 1/2
1 9/16	1.5625	—	—	18 NEF	—	—	16 N	1 9/16
1 5/8	1.6250	—	—	18 NEF	8 N	12 N	16 N	1 5/8
1 11/16	1.6875	—	—	18 NEF	—	12 N	16 N	1 11/16
1 3/4	1.7500	5 [c]	—	16 [c]	8 N	12 [c]	16 [c]	1 3/4
1 13/16	1.8125	—	—	—	—	—	16 N	1 13/16
1 7/8	1.8750	—	—	—	8 N	12 N	16 N	1 7/8
1 15/16	1.9375	—	—	—	—	—	16 N	1 15/16
2	2.0000	4 1/2 [c]	—	16 [c]	8 N	12 [c]	16 [c]	2
2 1/16	2.0625	—	—	—	—	—	16 N	2 1/16
2 1/8	2.1250	—	—	—	8 N	12 N	16 N	2 1/8
2 3/16	2.1875	—	—	—	—	—	16 N	2 3/16
2 1/4	2.2500	4 1/2 [c]	—	—	8 N	12 [c]	16 [c]	2 1/4
2 5/16	2.3125	—	—	—	—	—	16 N	2 5/16
2 3/8	2.3750	—	—	—	—	12 N	16 N	2 3/8
2 7/16	2.4375	—	—	—	—	—	16 N	2 7/16
2 1/2	2.5000	4 [c]	—	—	8 N	12 [c]	16 [c]	2 1/2
2 5/8	2.6250	—	—	—	—	12 N	16 N	2 5/8
2 3/4	2.7500	4 [c]	—	—	8 N	12 [c]	16 [c]	2 3/4
2 7/8	2.8750	—	—	—	—	12 N	16 N	2 7/8
3	3.0000	4 [c]	—	—	8 N	12 [c]	16 [c]	3
3 1/8	3.1250	—	—	—	—	12 N	16 N	3 1/8
3 1/4	3.2500	4 [c]	—	—	8 N	12 [c]	16 [c]	3 1/4
3 3/8	3.3750	—	—	—	—	12 N	16 N	3 3/8
3 1/2	3.5000	4 [c]	—	—	8 N	12 [c]	16 [c]	3 1/2
3 5/8	3.6250	—	—	—	—	12 N	16 N	3 5/8
3 3/4	3.7500	4 [c]	—	—	8 N	12 [c]	16 [c]	3 3/4
3 7/8	3.8750	—	—	—	—	12 N	16 N	3 7/8
4	4.0000	4 [c]	—	—	8 N	12 [c]	16 [c]	4
4 1/4	4.2500	—	—	—	8 N	12 [c]	16 [c]	4 1/4
4 1/2	4.5000	—	—	—	8 N	12 [c]	16 [c]	4 1/2
4 3/4	4.7500	—	—	—	8 N	12 [c]	16 [c]	4 3/4
5	5.0000	—	—	—	8 N	12 [c]	16 [c]	5
5 1/4	5.2500	—	—	—	8 N	12 [c]	16 [c]	5 1/4
5 1/2	5.5000	—	—	—	8 N	12 [c]	16 [c]	5 1/2
5 3/4	5.7500	—	—	—	8 N	12 [c]	16 [c]	5 3/4
6	6.0000	—	—	—	8 N	12 [c]	16 [c]	6

[a] For diameters over 1½ in., use 12-Thread Series.
[b] For diameters over 2 in., use 16-Thread Series.
[c] Series symbols UNC, UNF, or UN as indicated in column heading apply to Classes 1A, 1B, 2A, 2B, 3A, and 3B; NC, NF, NEF, or N as indicated in column heading apply to Classes 2 and 3.

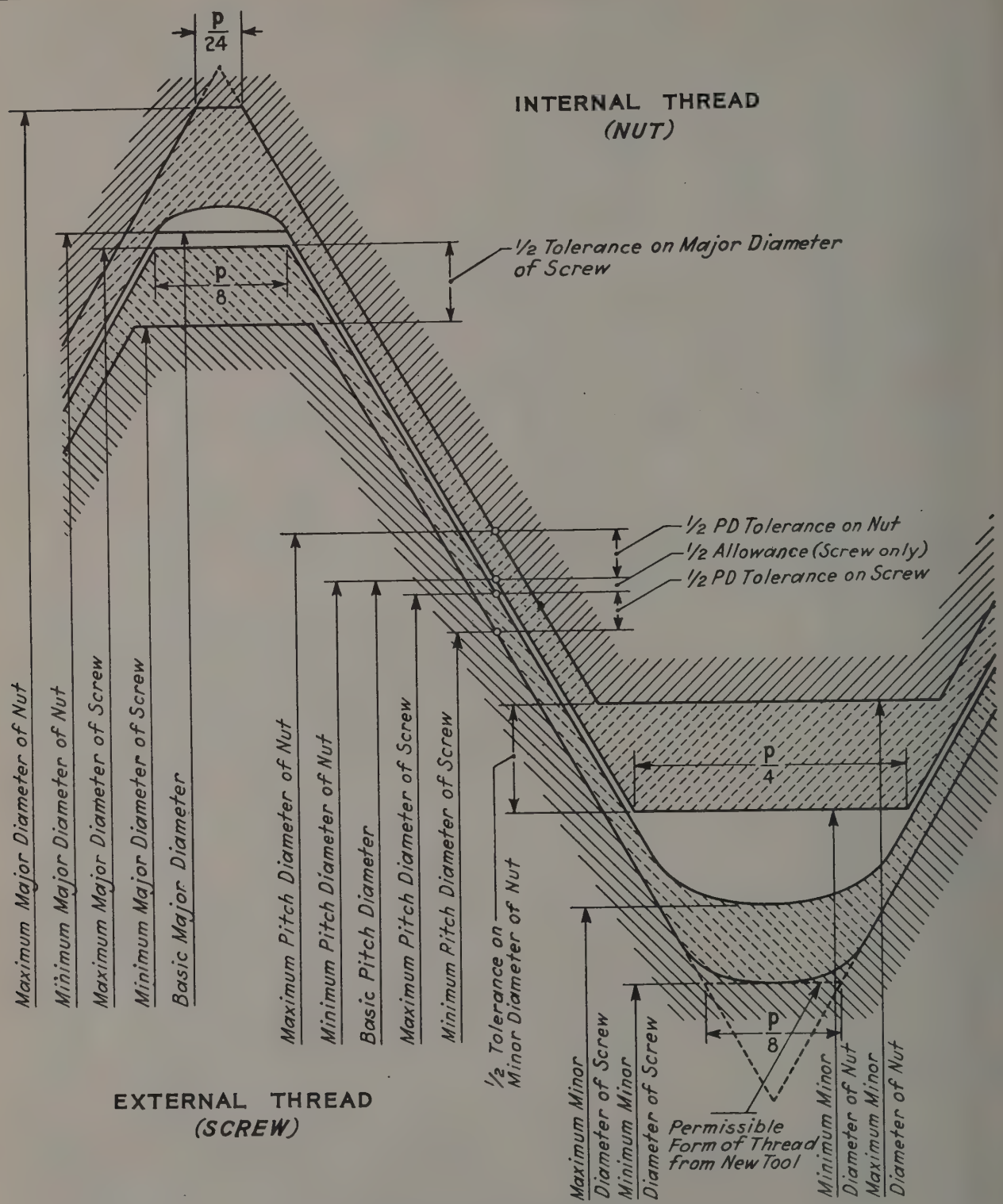

P/24
INTERNAL THREAD
(NUT)
½ Tolerance on Major Diameter of Screw
P/8
½ PD Tolerance on Nut
½ Allowance (Screw only)
½ PD Tolerance on Screw
Maximum Major Diameter of Nut
Minimum Major Diameter of Nut
Maximum Major Diameter of Screw
Minimum Major Diameter of Screw
Basic Major Diameter
Maximum Pitch Diameter of Nut
Minimum Pitch Diameter of Nut
Basic Pitch Diameter
Maximum Pitch Diameter of Screw
Minimum Pitch Diameter of Screw
½ Tolerance on Minor Diameter of Nut
P/4
P/8
Maximum Minor Diameter of Screw
Minimum Minor Diameter of Screw
Permissible Form of Thread from New Tool
Minimum Minor Diameter of Nut
Maximum Minor Diameter of Nut
EXTERNAL THREAD
(SCREW)

FIG. 2—DISPOSITION OF TOLERANCES, ALLOWANCE, AND CREST CLEARANCES FOR UNIFIED AND AMERICAN CLASSES 1A, 2A, 1B, AND 2B

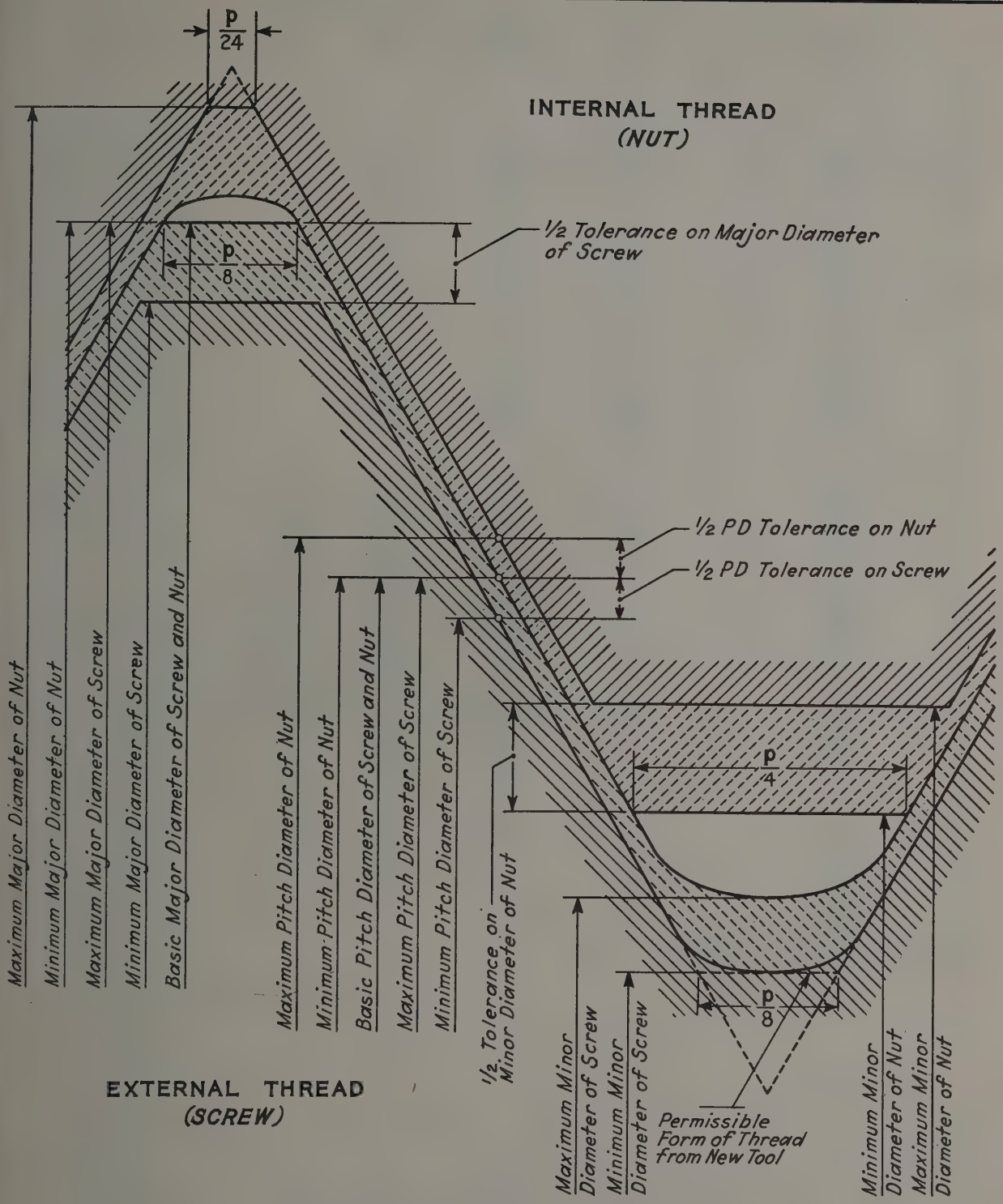

P/24
INTERNAL THREAD
(NUT)
½ Tolerance on Major Diameter of Screw
P/8
½ PD Tolerance on Nut
½ PD Tolerance on Screw
Maximum Major Diameter of Nut
Minimum Major Diameter of Nut
Maximum Major Diameter of Screw
Minimum Major Diameter of Screw
Basic Major Diameter of Screw and Nut
Maximum Pitch Diameter of Nut
Minimum Pitch Diameter of Nut
Basic Pitch Diameter of Screw and Nut
Maximum Pitch Diameter of Screw
Minimum Pitch Diameter of Screw
½ Tolerance on Minor Diameter of Nut
P/4
P/8
EXTERNAL THREAD
(SCREW)
Maximum Minor Diameter of Screw
Minimum Minor Diameter of Screw
Permissible Form of Thread from New Tool
Minimum Minor Diameter of Nut
Maximum Minor Diameter of Nut

FIG. 3—DISPOSITION OF TOLERANCES AND CREST CLEARANCES FOR UNIFIED AND AMERICAN CLASSES 3A, 3B, 2, AND 3

TABLE 3—*Coarse-Thread Series, UNC and NC—Basic Dimensions*

SIZES	BASIC MAJOR DIAMETER, D	THREADS PER INCH, n	BASIC PITCH DIAMETER,[a] E	MINOR DIAMETER EXTERNAL THREADS, K_s	MINOR DIAMETER INTERNAL THREADS, K_n	LEAD ANGLE AT BASIC PITCH DIAMETER, λ		SECTION AT MINOR DIAMETER AT $D-2h_b$	STRESS AREA[b]
	In.		In.	In.	In.	Deg	Min	Sq in.	Sq in.
1 (0.073)	0.0730	64	0.0629	0.0538	0.0561	4	31	0.0022	0.0026
2 (0.086)	0.0860	56	0.0744	0.0641	0.0667	4	22	0.0031	0.0036
3 (0.099)	0.0990	48	0.0855	0.0734	0.0764	4	26	0.0041	0.0048
4 (0.112)	0.1120	40	0.0958	0.0813	0.0849	4	45	0.0050	0.0060
5 (0.125)	0.1250	40	0.1088	0.0943	0.0979	4	11	0.0067	0.0079
6 (0.138)	0.1380	32	0.1177	0.0997	0.1042	4	50	0.0075	0.0090
8 (0.164)	0.1640	32	0.1437	0.1257	0.1302	3	58	0.0120	0.0139
10 (0.190)	0.1900	24	0.1629	0.1389	0.1449	4	39	0.0145	0.0174
12 (0.216)	0.2160	24	0.1889	0.1649	0.1709	4	1	0.0206	0.0240
1/4	0.2500	20	0.2175	0.1887	0.1959	4	11	0.0269	0.0317
5/16	0.3125	18	0.2764	0.2443	0.2524	3	40	0.0454	0.0522
3/8	0.3750	16	0.3344	0.2983	0.3073	3	24	0.0678	0.0773
7/16	0.4375	14	0.3911	0.3499	0.3602	3	20	0.0933	0.1060
1/2	0.5000	13	0.4500	0.4056	0.4167	3	7	0.1257	0.1416
1/2	0.5000	12	0.4459	0.3978	0.4098	3	24	0.1205	0.1374
9/16	0.5625	12	0.5084	0.4603	0.4723	2	59	0.1620	0.1816
5/8	0.6250	11	0.5660	0.5135	0.5266	2	56	0.2018	0.2256
3/4	0.7500	10	0.6850	0.6273	0.6417	2	40	0.3020	0.3340
7/8	0.8750	9	0.8028	0.7387	0.7547	2	31	0.4193	0.4612
1	1.0000	8	0.9188	0.8466	0.8647	2	29	0.5510	0.6051
1 1/8	1.1250	7	1.0322	0.9497	0.9704	2	31	0.6931	0.7627
1 1/4	1.2500	7	1.1572	1.0747	1.0954	2	15	0.8898	0.9684
1 3/8	1.3750	6	1.2667	1.1705	1.1946	2	24	1.0541	1.1538
1 1/2	1.5000	6	1.3917	1.2955	1.3196	2	11	1.2938	1.4041
1 3/4	1.7500	5	1.6201	1.5046	1.5335	2	15	1.7441	1.8983
2	2.0000	4 1/2	1.8557	1.7274	1.7594	2	11	2.3001	2.4971
2 1/4	2.2500	4 1/2	2.1057	1.9774	2.0094	1	55	3.0212	3.2464
2 1/2	2.5000	4	2.3376	2.1933	2.2294	1	57	3.7161	3.9976
2 3/4	2.7500	4	2.5876	2.4433	2.4794	1	46	4.6194	4.9326
3	3.0000	4	2.8376	2.6933	2.7294	1	36	5.6209	5.9659
3 1/4	3.2500	4	3.0876	2.9433	2.9794	1	29	6.7205	7.0992
3 1/2	3.5000	4	3.3376	3.1933	3.2294	1	22	7.9183	8.3268
3 3/4	3.7500	4	3.5876	3.4433	3.4794	1	16	9.2143	9.6546
4	4.0000	4	3.8376	3.6933	3.7294	1	11	10.6084	11.0805

[a] British: Effective Diameter.
[b] See formula under definition of stress area in Appendix A, Terminology.

TABLE 4—*Fine-Thread Series, UNF and NF—Basic Dimensions*

SIZES	BASIC MAJOR DIAMETER, D	THREADS PER INCH, n	BASIC PITCH DIAMETER,[a] E	MINOR DIAMETER EXTERNAL THREADS, K_s	MINOR DIAMETER INTERNAL THREADS, K_n	LEAD ANGLE AT BASIC PITCH DIAMETER, λ		SECTION AT MINOR DIAMETER at $D-2h_b$	STRESS AREA[b]
	In.		In.	In.	In.	Deg	Min	Sq in.	Sq in.
0 (0.060)	0.0600	80	0.0519	0.0447	0.0465	4	23	0.0015	0.0018
1 (0.073)	0.0730	72	0.0640	0.0560	0.0580	3	57	0.0024	0.0027
2 (0.086)	0.0860	64	0.0759	0.0668	0.0691	3	45	0.0034	0.0039
3 (0.099)	0.0990	56	0.0874	0.0771	0.0797	3	43	0.0045	0.0052
4 (0.112)	0.1120	48	0.0985	0.0864	0.0894	3	51	0.0057	0.0065
5 (0.125)	0.1250	44	0.1102	0.0971	0.1004	3	45	0.0072	0.0082
6 (0.138)	0.1380	40	0.1218	0.1073	0.1109	3	44	0.0087	0.0101
8 (0.164)	0.1640	36	0.1460	0.1299	0.1339	3	28	0.0128	0.0146
10 (0.190)	0.1900	32	0.1697	0.1517	0.1562	3	21	0.0175	0.0199
12 (0.216)	0.2160	28	0.1928	0.1722	0.1773	3	22	0.0226	0.0257
1/4	0.2500	28	0.2268	0.2062	0.2113	2	52	0.0326	0.0362
5/16	0.3125	24	0.2854	0.2614	0.2674	2	40	0.0524	0.0579
3/8	0.3750	24	0.3479	0.3239	0.3299	2	11	0.0809	0.0876
7/16	0.4375	20	0.4050	0.3762	0.3834	2	15	0.1090	0.1185
1/2	0.5000	20	0.4675	0.4387	0.4459	1	57	0.1486	0.1597
9/16	0.5625	18	0.5264	0.4943	0.5024	1	55	0.1888	0.2026
5/8	0.6250	18	0.5889	0.5568	0.5649	1	43	0.2400	0.2555
3/4	0.7500	16	0.7094	0.6733	0.6823	1	36	0.3513	0.3724
7/8	0.8750	14	0.8286	0.7874	0.7977	1	34	0.4805	0.5088
1	1.0000	14	0.9536	0.9124	0.9227	1	22	0.6464	0.6791
1	1.0000	12	0.9459	0.8978	0.9098	1	36	0.6245	0.6624
1 1/8	1.1250	12	1.0709	1.0228	1.0348	1	25	0.8118	0.8549
1 1/4	1.2500	12	1.1959	1.1478	1.1598	1	16	1.0237	1.0721
1 3/8	1.3750	12	1.3209	1.2728	1.2848	1	9	1.2602	1.3137
1 1/2	1.5000	12	1.4459	1.3978	1.4098	1	3	1.5212	1.5799

[a] British: Effective Diameter.
[b] See formula under definition of stress area in Appendix A, Terminology.

TABLE 5—*Extra-Fine Thread Series, NEF*[a]*—Basic Dimensions*

SIZES	BASIC MAJOR DIAMETER, D	THREADS PER INCH, n	BASIC PITCH DIAMETER,[b] E	MINOR DIAMETER EXTERNAL THREADS, K_s	MINOR DIAMETER INTERNAL THREADS, K_n	LEAD ANGLE AT BASIC PITCH DIAMETER, λ		SECTION AT MINOR DIAMETER AT $D-2h_b$	STRESS AREA[c]
	In.		In.	In.	In.	Deg	Min	Sq in.	Sq in.
12 (0.216)	0.2160	32	0.1957	0.1777	0.1822	2	55	0.0242	0.0269
1/4	0.2500	32	0.2297	0.2117	0.2162	2	29	0.0344	0.0377
5/16	0.3125	32	0.2922	0.2742	0.2787	1	57	0.0581	0.0622
3/8	0.3750	32	0.3547	0.3367	0.3412	1	36	0.0878	0.0929
7/16	0.4375	28	0.4143	0.3937	0.3988	1	34	0.1201	0.1270
1/2	0.5000	28	0.4768	0.4562	0.4613	1	22	0.1616	0.1695
9/16	0.5625	24	0.5354	0.5114	0.5174	1	25	0.2030	0.2134
5/8	0.6250	24	0.5979	0.5739	0.5799	1	16	0.2560	0.2676
11/16	0.6875	24	0.6604	0.6364	0.6424	1	9	0.3151	0.3280
3/4	0.7500	20	0.7175	0.6887	0.6959	1	16	0.3685	0.3855
13/16	0.8125	20	0.7800	0.7512	0.7584	1	10	0.4388	0.4573
7/8	0.8750	20	0.8425	0.8137	0.8209	1	5	0.5153	0.5352
15/16	0.9375	20	0.9050	0.8762	0.8834	1	0	0.5979	0.6194
1	1.0000	20	0.9675	0.9387	0.9459	0	57	0.6866	0.7095
1 1/16	1.0625	18	1.0264	0.9943	1.0024	0	59	0.7702	0.7973
1 1/8	1.1250	18	1.0889	1.0568	1.0649	0	56	0.8705	0.8993
1 3/16	1.1875	18	1.1514	1.1193	1.1274	0	53	0.9770	1.0074
1 1/4	1.2500	18	1.2139	1.1818	1.1899	0	50	1.0895	1.1216
1 5/16	1.3125	18	1.2764	1.2443	1.2524	0	48	1.2082	1.2420
1 3/8	1.3750	18	1.3389	1.3068	1.3149	0	45	1.3330	1.3684
1 7/16	1.4375	18	1.4014	1.3693	1.3774	0	43	1.4640	1.5010
1 1/2	1.5000	18	1.4639	1.4318	1.4399	0	42	1.6011	1.6397
1 9/16	1.5625	18	1.5264	1.4943	1.5024	0	40	1.7444	1.7846
1 5/8	1.6250	18	1.5889	1.5568	1.5649	0	38	1.8937	1.9357
1 11/16	1.6875	18	1.6514	1.6193	1.6274	0	37	2.0493	2.0929
1 3/4	1.7500	16	1.7094	1.6733	1.6823	0	40	2.1873	2.2382
2	2.0000	16	1.9594	1.9233	1.9323	0	35	2.8917	2.9501

[a] Certain sizes are designated UNEF in Tables 17 and 18.
[b] British: Effective Diameter.
[c] See formula under definition of stress area in Appendix A, Terminology.

TABLE 6—*8-Thread Series, 8N—Basic Dimensions*

SIZES	BASIC MAJOR DIAMETER, D	BASIC PITCH DIAMETER,[a] E	MINOR DIAMETER EXTERNAL THREADS, K_s	MINOR DIAMETER INTERNAL THREADS, K_n	LEAD ANGLE AT BASIC PITCH DIAMETER, λ		SECTION AT MINOR DIAMETER AT $D-2h_b$	STRESS AREA[b]
In.	In.	In.	In.	In.	Deg	Min	Sq in.	Sq in.
1	1.0000	0.9188	0.8466	0.8647	2	29	0.5510	0.6051
1⅛	1.1250	1.0438	0.9716	0.9897	2	11	0.7277	0.7896
1¼	1.2500	1.1688	1.0966	1.1147	1	57	0.9290	0.9985
1⅜	1.3750	1.2938	1.2216	1.2397	1	46	1.1548	1.2319
1½	1.5000	1.4188	1.3466	1.3647	1	36	1.4052	1.4899
1⅝	1.6250	1.5438	1.4716	1.4897	1	29	1.6801	1.7723
1¾[c]	1.7500	1.6688	1.5966	1.6147	1	22	1.9796	2.0792
1⅞	1.8750	1.7938	1.7216	1.7397	1	16	2.3036	2.4107
2[c]	2.0000	1.9188	1.8466	1.8647	1	11	2.6521	2.7665
2⅛	2.1250	2.0438	1.9716	1.9897	1	7	3.0252	3.1469
2¼[c]	2.2500	2.1688	2.0966	2.1147	1	3	3.4228	3.5519
2½[c]	2.5000	2.4188	2.3466	2.3647	0	57	4.2917	4.4352
2¾[c]	2.7500	2.6688	2.5966	2.6147	0	51	5.2588	5.4164
3[c]	3.0000	2.9188	2.8466	2.8647	0	47	6.3240	6.4957
3¼[c]	3.2500	3.1688	3.0966	3.1147	0	43	7.4874	7.6738
3½[c]	3.5000	3.4188	3.3466	3.3647	0	40	8.7490	8.9504
3¾[c]	3.7500	3.6688	3.5966	3.6147	0	37	10.1088	10.3249
4[c]	4.0000	3.9188	3.8466	3.8647	0	35	11.5667	11.7975
4¼[c]	4.2500	4.1688	4.0966	4.1147	0	33	13.1228	13.3683
4½[c]	4.5000	4.4188	4.3466	4.3647	0	31	14.7771	15.0372
4¾[c]	4.7500	4.6688	4.5966	4.6147	0	29	16.5295	16.8042
5[c]	5.0000	4.9188	4.8466	4.8647	0	28	18.3802	18.6694
5¼[c]	5.2500	5.1688	5.0966	5.1147	0	26	20.3290	20.6330
5½[c]	5.5000	5.4188	5.3466	5.3647	0	25	22.3760	22.6945
5¾[c]	5.7500	5.6688	5.5966	5.6147	0	24	24.5211	24.8541
6[c]	6.0000	5.9188	5.8466	5.8647	0	23	26.7645	27.1118

[a] British: Effective Diameter.
[b] See formula under definition of stress area in Appendix A, Terminology.
[c] These sizes with specified limits of size, based on length of engagement of 9 threads, are designated UN in Tables 17 and 18.

TABLE 7—*12-Thread Series, 12N*[a]*—Basic Dimensions*

SIZES	BASIC MAJOR DIAMETER, D	BASIC PITCH DIAMETER,[b] E	MINOR DIAMETER EXTERNAL THREADS, K_s	MINOR DIAMETER INTERNAL THREADS, K_n	LEAD ANGLE AT BASIC PITCH DIAMETER, λ		SECTION AT MINOR DIAMETER AT $D-2K_5$	STRESS AREA[c]
In.	In.	In.	In.	In.	Deg	Min	Sq in.	Sq in.
1/2	0.5000	0.4459	0.3978	0.4098	3	24	0.1205	0.1374
9/16	0.5625	0.5084	0.4603	0.4723	2	59	0.1620	0.1816
5/8	0.6250	0.5709	0.5228	0.5348	2	40	0.2097	0.2319
11/16	0.6875	0.6334	0.5853	0.5973	2	24	0.2635	0.2883
3/4	0.7500	0.6959	0.6478	0.6598	2	11	0.3234	0.3508
13/16	0.8125	0.7584	0.7103	0.7223	2	0	0.3895	0.4195
7/8	0.8750	0.8209	0.7728	0.7848	1	51	0.4617	0.4943
15/16	0.9375	0.8834	0.8353	0.8473	1	43	0.5400	0.5753
1	1.0000	0.9459	0.8978	0.9098	1	36	0.6245	0.6624
1 1/16	1.0625	1.0084	0.9603	0.9723	1	30	0.7151	0.7556
1 1/8	1.1250	1.0709	1.0228	1.0348	1	25	0.8118	0.8550
1 3/16	1.1875	1.1334	1.0853	1.0973	1	20	0.9147	0.9604
1 1/4	1.2500	1.1959	1.1478	1.1598	1	16	1.0237	1.0721
1 5/16	1.3125	1.2584	1.2103	1.2223	1	12	1.1389	1.1898
1 3/8	1.3750	1.3209	1.2728	1.2848	1	9	1.2602	1.3138
1 7/16	1.4375	1.3834	1.3353	1.3473	1	6	1.3876	1.4438
1 1/2	1.5000	1.4459	1.3978	1.4098	1	3	1.5212	1.5800
1 5/8	1.6250	1.5709	1.5228	1.5348	0	58	1.8067	1.8701
1 3/4	1.7500	1.6959	1.6478	1.6598	0	54	2.1168	2.1853
1 7/8	1.8750	1.8209	1.7728	1.7848	0	50	2.4514	2.5250
2	2.0000	1.9459	1.8978	1.9098	0	47	2.8106	2.8892
2 1/8	2.1250	2.0709	2.0228	2.0348	0	44	3.1943	3.2779
2 1/4	2.2500	2.1959	2.1478	2.1598	0	42	3.6025	3.6914
2 3/8	2.3750	2.3209	2.2728	2.2848	0	39	4.0353	4.1291
2 1/2	2.5000	2.4459	2.3978	2.4098	0	37	4.4927	4.5916
2 5/8	2.6250	2.5709	2.5228	2.5348	0	35	4.9745	5.0784
2 3/4	2.7500	2.6959	2.6478	2.6598	0	34	5.4810	5.5900
2 7/8	2.8750	2.8209	2.7728	2.7848	0	32	6.0119	6.1259
3	3.0000	2.9459	2.8978	2.9098	0	31	6.5674	6.6865
3 1/8	3.1250	3.0709	3.0228	3.0348	0	30	7.1475	7.2714
3 1/4	3.2500	3.1959	3.1478	3.1598	0	29	7.7521	7.8812
3 3/8	3.3750	3.3209	3.2728	3.2848	0	27	8.3812	8.5152
3 1/2	3.5000	3.4459	3.3978	3.4098	0	26	9.0349	9.1740
3 5/8	3.6250	3.5709	3.5228	3.5348	0	26	9.7132	9.8570
3 3/4	3.7500	3.6959	3.6478	3.6598	0	25	10.4159	10.5649
3 7/8	3.8750	3.8209	3.7728	3.7848	0	24	11.1433	11.2970
4	4.0000	3.9459	3.8978	3.9098	0	23	11.8951	12.0540
4 1/4	4.2500	4.1959	4.1478	4.1598	0	22	13.4725	13.6411
4 1/2	4.5000	4.4459	4.3978	4.4098	0	21	15.1480	15.3265
4 3/4	4.7500	4.6959	4.6478	4.6598	0	19	16.9217	17.1099
5	5.0000	4.9459	4.8978	4.9098	0	18	18.7936	18.9916
5 1/4	5.2500	5.1959	5.1478	5.1598	0	18	20.7636	20.9717
5 1/2	5.5000	5.4459	5.3978	5.4098	0	17	22.8319	23.0496
5 3/4	5.7500	5.6959	5.6478	5.6598	0	16	24.9983	25.2257
6	6.0000	5.9459	5.8978	5.9098	0	15	27.2628	27.4998

[a] Certain sizes are designated UN in Tables 17 and 18.
[b] British: Effective Diameter.
[c] See formula under definition of stress area in Appendix A, Terminology.

TABLE 8—*16-Thread Series, 16N*[a]*—Basic Dimensions*

SIZES	BASIC MAJOR DIAMETER, D	BASIC PITCH DIAMETER,[b] E	MINOR DIAMETER EXTERNAL THREADS, K_s	MINOR DIAMETER INTERNAL THREADS, K_n	LEAD ANGLE AT BASIC PITCH DIAMETER, λ		SECTION AT MINOR DIAMETER AT $D-2h_b$	STRESS AREA[c]
In.	In.	In.	In.	In.	Deg	Min	Sq in.	Sq in.
3/4	0.7500	0.7094	0.6733	0.6823	1	36	0.3513	0.3724
13/16	0.8125	0.7719	0.7358	0.7448	1	29	0.4200	0.4429
7/8	0.8750	0.8344	0.7983	0.8073	1	22	0.4949	0.5197
15/16	0.9375	0.8969	0.8608	0.8698	1	16	0.5759	0.6025
1	1.0000	0.9594	0.9233	0.9323	1	11	0.6630	0.6916
1 1/16	1.0625	1.0219	0.9858	0.9948	1	7	0.7563	0.7867
1 1/8	1.1250	1.0844	1.0483	1.0573	1	3	0.8557	0.8880
1 3/16	1.1875	1.1469	1.1108	1.1198	1	0	0.9612	0.9955
1 1/4	1.2500	1.2094	1.1733	1.1823	0	57	1.0729	1.1090
1 5/16	1.3125	1.2719	1.2358	1.2448	0	54	1.1907	1.2287
1 3/8	1.3750	1.3344	1.2983	1.3073	0	51	1.3147	1.3545
1 7/16	1.4375	1.3969	1.3608	1.3698	0	49	1.4448	1.4865
1 1/2	1.5000	1.4594	1.4233	1.4323	0	47	1.5810	1.6246
1 9/16	1.5625	1.5219	1.4858	1.4948	0	45	1.7234	1.7687
1 5/8	1.6250	1.5844	1.5483	1.5573	0	43	1.8719	1.9191
1 11/16	1.6875	1.6469	1.6108	1.6198	0	42	2.0265	2.0757
1 3/4	1.7500	1.7094	1.6733	1.6823	0	40	2.1873	2.2382
1 13/16	1.8125	1.7719	1.7358	1.7448	0	39	2.3542	2.4070
1 7/8	1.8750	1.8344	1.7983	1.8073	0	37	2.5272	2.5819
1 15/16	1.9375	1.8969	1.8608	1.8698	0	36	2.7064	2.7629
2	2.0000	1.9594	1.9233	1.9323	0	35	2.8917	2.9501
2 1/16	2.0625	2.0219	1.9858	1.9948	0	34	3.0831	3.1434
2 1/8	2.1250	2.0844	2.0483	2.0573	0	33	3.2807	3.3427
2 3/16	2.1875	2.1469	2.1108	2.1198	0	32	3.4844	3.5483
2 1/4	2.2500	2.2094	2.1733	2.1823	0	31	3.6943	3.7601
2 5/16	2.3125	2.2719	2.2358	2.2448	0	30	3.9103	3.9780
2 3/8	2.3750	2.3344	2.2983	2.3073	0	29	4.1324	4.2018
2 7/16	2.4375	2.3969	2.3608	2.3698	0	29	4.3606	4.4319
2 1/2	2.5000	2.4594	2.4233	2.4323	0	28	4.5950	4.6682
2 5/8	2.6250	2.5844	2.5483	2.5573	0	26	5.0822	5.1790
2 3/4	2.7500	2.7094	2.6733	2.6823	0	25	5.5940	5.6745
2 7/8	2.8750	2.8344	2.7983	2.8073	0	24	6.1303	6.2143
3	3.0000	2.9594	2.9233	2.9323	0	23	6.6911	6.7789
3 1/8	3.1250	3.0844	3.0483	3.0573	0	22	7.2765	7.3678
3 1/4	3.2500	3.2094	3.1733	3.1823	0	21	7.8864	7.9814
3 3/8	3.3750	3.3344	3.2983	3.3073	0	21	8.5209	8.6194
3 1/2	3.5000	3.4594	3.4233	3.4323	0	20	9.1799	9.2821
3 5/8	3.6250	3.5844	3.5483	3.5573	0	19	9.8634	9.9691
3 3/4	3.7500	3.7094	3.6733	3.6823	0	18	10.5715	10.6809
3 7/8	3.8750	3.8344	3.7983	3.8073	0	18	11.3042	11.4170
4	4.0000	3 9594	3.9233	3.9323	0	17	12.0614	12.1779
4 1/4	4.2500	4.2094	4.1733	4.1823	0	16	13.6494	13.7730
4 1/2	4 5000	4.4594	4.4233	4.4323	0	15	15.3355	15.4662
4 3/4	4.7500	4.7094	4.6733	4.6823	0	15	17.1199	17.2575
5	5.0000	4.9594	4.9233	4.9323	0	14	19.0024	19.1470
5 1/4	5.2500	5.2094	5.1733	5.1823	0	13	20.9831	21.1350
5 1/2	5.5000	5.4594	5.4233	5.4323	0	13	23.0620	23.2208
5 3/4	5.7500	5.7094	5.6733	5.6823	0	12	25.2390	25.4047
6	6.0000	5.9594	5.9233	5.9323	0	11	27.5142	27.6868

[a] Certain sizes are designated UN in Tables 17 and 18.
[b] British: Effective Diameter.
[c] See formula under definition of stress area in Appendix A, Terminology.

TABLE 9—*Class 1A, External Threads—UNC, UNF, NC, and NF Series*

DESIGNATION			EXTERNAL-THREAD LIMITS OF SIZE							
				Major diameter			Pitch diameter[a]			
Size	Threads per inch	Thread symbol	Allowance	Limits		Tolerance	Limits		Tolerance	Minor diameter[b]
				Max	Min		Max	Min		
1/4	20	UNC-1A	0.0011	0.2489	0.2367	0.0122	0.2164	0.2108	0.0056	0.1876
1/4	28	UNF-1A	0.0010	0.2490	0.2392	0.0098	0.2258	0.2208	0.0050	0.2052
5/16	18	UNC-1A	0.0012	0.3113	0.2982	0.0131	0.2752	0.2691	0.0061	0.2431
5/16	24	UNF-1A	0.0011	0.3114	0.3006	0.0108	0.2843	0.2788	0.0055	0.2603
3/8	16	UNC-1A	0.0013	0.3737	0.3595	0.0142	0.3331	0.3266	0.0065	0.2970
3/8	24	UNF-1A	0.0011	0.3739	0.3631	0.0108	0.3468	0.3411	0.0057	0.3228
7/16	14	UNC-1A	0.0014	0.4361	0.4206	0.0155	0.3897	0.3826	0.0071	0.3485
7/16	20	UNF-1A	0.0013	0.4362	0.4240	0.0122	0.4037	0.3975	0.0062	0.3749
1/2	13	NC-1A	0.0015	0.4985	0.4822	0.0163	0.4485	0.4411	0.0074	0.4041
1/2	12	UNC-1A	0.0015	0.4985	0.4813	0.0172	0.4444	0.4367	0.0077	0.3963
1/2	20	UNF-1A	0.0013	0.4987	0.4865	0.0122	0.4662	0.4598	0.0064	0.4374
9/16	12	UNC-1A	0.0016	0.5609	0.5437	0.0172	0.5068	0.4990	0.0078	0.4587
9/16	18	UNF-1A	0.0014	0.5611	0.5480	0.0131	0.5250	0.5182	0.0068	0.4929
5/8	11	UNC-1A	0.0016	0.6234	0.6052	0.0182	0.5644	0.5561	0.0083	0.5119
5/8	18	UNF-1A	0.0014	0.6236	0.6105	0.0131	0.5875	0.5805	0 0070	0.5554
3/4	10	UNC-1A	0.0018	0.7482	0.7288	0.0194	0.6832	0.6744	0.0088	0.6255
3/4	16	UNF-1A	0.0015	0.7485	0.7343	0.0142	0.7079	0.7004	0.0075	0.6718
7/8	9	UNC-1A	0.0019	0.8731	0.8523	0.0208	0.8009	0.7914	0.0095	0.7368
7/8	14	UNF-1A	0.0016	0.8734	0.8579	0.0155	0.8270	0.8189	0.0081	0.7858
1	8	UNC-1A	0.0020	0.9980	0.9755	0.0225	0.9168	0.9067	0.0101	0.8446
1	12	UNF-1A	0.0018	0.9982	0.9810	0.0172	0.9441	0.9353	0.0088	0.8960
1	14	NF-1A	0.0017	0.9983	0.9828	0.0155	0.9519	0.9435	0.0084	0.9107
1 1/8	7	UNC-1A	0.0022	1.1228	1.0982	0.0246	1.0300	1.0191	0.0109	0.9475
1 1/8	12	UNF-1A	0.0018	1.1232	1.1060	0.0172	1.0691	1.0601	0.0090	1.0210
1 1/4	7	UNC-1A	0.0022	1.2478	1.2232	0.0246	1.1550	1.1439	0.0111	1.0725
1 1/4	12	UNF-1A	0.0018	1.2482	1.2310	0.0172	1.1941	1.1849	0.0092	1.1460
1 3/8	6	UNC-1A	0.0024	1.3726	1.3453	0.0273	1.2643	1.2523	0.0120	1.1681
1 3/8	12	UNF-1A	0.0019	1.3731	1.3559	0.0172	1.3190	1.3096	0.0094	1.2709
1 1/2	6	UNC-1A	0.0024	1.4976	1.4703	0.0273	1.3893	1.3772	0.0121	1.2931
1 1/2	12	UNF-1A	0.0019	1.4981	1.4809	0.0172	1.4440	1.4344	0.0096	1.3959
1 3/4	5	UNC-1A	0.0027	1.7473	1.7165	0.0308	1.6174	1.6040	0.0134	1.5019
2	4 1/2	UNC-1A	0.0029	1.9971	1.9641	0.0330	1.8528	1.8385	0.0143	1.7245
2 1/4	4 1/2	UNC-1A	0.0029	2.2471	2.2141	0.0330	2.1028	2.0882	0.0146	1.9745
2 1/2	4	UNC-1A	0.0031	2.4969	2.4612	0.0357	2.3345	2.3190	0.0155	2.1902
2 3/4	4	UNC-1A	0.0032	2.7468	2.7111	0.0357	2.5844	2.5686	0.0158	2.4401
3	4	UNC-1A	0.0032	2.9968	2.9611	0.0357	2.8344	2.8183	0.0161	2.6901
3 1/4	4	UNC-1A	0.0033	3.2467	3.2110	0.0357	3.0843	3.0680	0.0163	2.9400
3 1/2	4	UNC-1A	0.0033	3.4967	3.4610	0.0357	3.3343	3.3177	0.0166	3.1900
3 3/4	4	UNC-1A	0.0034	3.7466	3.7109	0.0357	3.5842	3.5674	0.0168	3.4399
4	4	UNC-1A	0.0034	3.9966	3.9609	0.0357	3.8342	3.8172	0.0170	3.6899

[a] British: Effective Diameter.
[b] See Fig. 1.

TABLE 10a—*Class 2A, External Threads—UNC, UNF, NC, NF, and 8N Series*

DESIGNATION			EXTERNAL-THREAD LIMITS OF SIZE								
				Major diameter					Pitch diameter[a]			
				Limits			Tolerance		Limits			
Size	Threads per inch	Thread symbol	Allowance	Max[c]	Min[d]	Min[e]	d	e	Max[c]	Min	Tolerance	Minor diameter[b]
0 (0.060)	80	NF-2A	0.0005	0.0595	0.0563	—	0.0032	—	0.0514	0.0496	0.0018	0.0442
1 (0.073)	64	NC-2A	0.0006	0.0724	0.0686	—	0.0038	—	0.0623	0.0603	0.0020	0.0532
1 (0.073)	72	NF-2A	0.0006	0.0724	0.0689	—	0.0035	—	0.0634	0.0615	0.0019	0.0554
2 (0.086)	56	NC-2A	0.0006	0.0854	0.0813	—	0.0041	—	0.0738	0.0717	0.0021	0.0635
2 (0.086)	64	NF-2A	0.0006	0.0854	0.0816	—	0.0038	—	0.0753	0.0733	0.0020	0.0662
3 (0.099)	48	NC-2A	0.0007	0.0983	0.0938	—	0.0045	—	0.0848	0.0825	0.0023	0.0727
3 (0.099)	56	NF-2A	0.0007	0.0983	0.0942	—	0.0041	—	0.0867	0.0845	0.0022	0.0764
4 (0.112)	40	NC-2A	0.0008	0.1112	0.1061	—	0.0051	—	0.0950	0.0925	0.0025	0.0805
4 (0.112)	48	NF-2A	0.0007	0.1113	0.1068	—	0.0045	—	0.0978	0.0954	0.0024	0.0857
5 (0.125)	40	NC-2A	0.0008	0.1242	0.1191	—	0.0051	—	0.1080	0.1054	0.0026	0.0935
5 (0.125)	44	NF-2A	0.0007	0.1243	0.1195	—	0.0048	—	0.1095	0.1070	0.0025	0.0964
6 (0.138)	32	NC-2A	0.0008	0.1372	0.1312	—	0.0060	—	0.1169	0.1141	0.0028	0.0989
6 (0.138)	40	NF-2A	0.0008	0.1372	0.1321	—	0.0051	—	0.1210	0.1184	0.0026	0.1065
8 (0.164)	32	NC-2A	0.0009	0.1631	0.1571	—	0.0060	—	0.1428	0.1399	0.0029	0.1248
8 (0.164)	36	NF-2A	0.0008	0.1632	0.1577	—	0.0055	—	0.1452	0.1424	0.0028	0.1291
10 (0.190)	24	NC-2A	0.0010	0.1890	0.1818	—	0.0072	—	0.1619	0.1586	0.0033	0.1379
10 (0.190)	32	NF-2A	0.0009	0.1891	0.1831	—	0.0060	—	0.1688	0.1658	0.0030	0.1508
12 (0.216)	24	NC-2A	0.0010	0.2150	0.2078	—	0.0072	—	0.1879	0.1845	0.0034	0.1639
12 (0.216)	28	NF-2A	0.0010	0.2150	0.2085	—	0.0065	—	0.1918	0.1886	0.0032	0.1712
1/4	20	UNC-2A	0.0011	0.2489	0.2408	0.2367	0.0081	0.0122	0.2164	0.2127	0.0037	0.1876
1/4	28	UNF-2A	0.0010	0.2490	0.2425	—	0.0065	—	0.2258	0.2225	0.0033	0.2052
5/16	18	UNC-2A	0.0012	0.3113	0.3026	0.2982	0.0087	0.0131	0.2752	0.2712	0.0040	0.2431
5/16	24	UNF-2A	0.0011	0.3114	0.3042	—	0.0072	—	0.2843	0.2806	0.0037	0.2603
3/8	16	UNC-2A	0.0013	0.3737	0.3643	0.3595	0.0094	0.0142	0.3331	0.3287	0.0044	0.2970
3/8	24	UNF-2A	0.0011	0.3739	0.3667	—	0.0072	—	0.3468	0.3430	0.0038	0.3228
7/16	14	UNC-2A	0.0014	0.4361	0.4258	0.4206	0.0103	0.0155	0.3897	0.3850	0.0047	0.3485
7/16	20	UNF-2A	0.0013	0.4362	0.4281	—	0.0081	—	0.4037	0.3995	0.0042	0.3749
1/2	13	NC-2A	0.0015	0.4985	0.4876	0.4822	0.0109	0.0163	0.4485	0.4435	0.0050	0.4041
1/2	12	UNC-2A	0.0015	0.4985	0.4871	0.4813	0.0114	0.0172	0.4444	0.4393	0.0051	0.3963
1/2	20	UNF-2A	0.0013	0.4987	0.4906	—	0.0081	—	0.4662	0.4619	0.0043	0.4374
9/16	12	UNC-2A	0.0016	0.5609	0.5495	0.5437	0.0114	0.0172	0.5068	0.5016	0.0052	0.4587
9/16	18	UNF-2A	0.0014	0.5611	0.5524	—	0.0087	—	0.5250	0.5205	0.0045	0.4929
5/8	11	UNC-2A	0.0016	0.6234	0.6113	0.6052	0.0121	0.0182	0.5644	0.5589	0.0055	0.5119
5/8	18	UNF-2A	0.0014	0.6236	0.6149	—	0.0087	—	0.5875	0.5828	0.0047	0.5554
3/4	10	UNC-2A	0.0018	0.7482	0.7353	0.7288	0.0129	0.0194	0.6832	0.6773	0.0059	0.6255
3/4	16	UNF-2A	0.0015	0.7485	0.7391	—	0.0094	—	0.7079	0.7029	0.0050	0.6718
7/8	9	UNC-2A	0.0019	0.8731	0.8592	0.8523	0.0139	0.0208	0.8009	0.7946	0.0063	0.7368
7/8	14	UNF-2A	0.0016	0.8734	0.8631	—	0.0103	—	0.8270	0.8216	0.0054	0.7858
1	8	UNC-2A	0.0020	0.9980	0.9830	0.9755	0.0150	0.0225	0.9168	0.9100	0.0068	0.8446
1	12	UNF-2A	0.0018	0.9982	0.9868	—	0.0114	—	0.9441	0.9382	0.0059	0.8960
1	14	NF-2A	0.0017	0.9983	0.9880	—	0.0103	—	0.9519	0.9463	0.0056	0.9107
1 1/8	7	UNC-2A	0.0022	1.1228	1.1064	1.0982	0.0164	0.0246	1.0300	1.0228	0.0072	0.9475
1 1/8	8	N-2A	0.0021	1.1229	1.1079	1.1004	0.0150	0.0225	1.0417	1.0348	0.0069	0.9695
1 1/8	12	UNF-2A	0.0018	1.1232	1.1118	—	0.0114	—	1.0691	1.0631	0.0060	1.0210

[a] British: Effective Diameter.
[b] See Fig. 1.
[c] Maximum limits are increased by the amount of the allowance for threads which are electroplated or have coatings of similar thicknesses. Where the allowance is not sufficient for the required thickness of plating or coating, special provisions are necessary.
[d] For semi-finished and finished screws and bolts, threaded portion only.
[e] For unfinished hot-rolled material, threaded portion only.

TABLE 10b—*Class 2A, External Threads—UNC, UNF, NC, NF, and 8N Series*

DESIGNATION			EXTERNAL-THREAD LIMITS OF SIZE									
				Major diameter					Pitch diameter[a]			
				Limits			Tolerance		Limits		Tolerance	Minor diameter[b]
Size	Threads per inch	Thread symbol	Allowance	Max[c]	Min[d]	Min[e]	[d]	[e]	Max[c]	Min		
1¼	7	UNC-2A	0.0022	1.2478	1.2314	1.2232	0.0164	0.0246	1.1550	1.1476	0.0074	1.0725
1¼	8	N-2A	0.0021	1.2479	1.2329	1.2254	0.0150	0.0225	1.1667	1.1597	0.0070	1.0945
1¼	12	UNF-2A	0.0018	1.2482	1.2368	—	0.0114	—	1.1941	1.1879	0.0062	1.1460
1⅜	6	UNC-2A	0.0024	1.3726	1.3544	1.3453	0.0182	0.0273	1.2643	1.2563	0.0080	1.1681
1⅜	8	N-2A	0.0022	1.3728	1.3578	1.3503	0.0150	0.0225	1.2916	1.2844	0.0072	1.2194
1⅜	12	UNF-2A	0.0019	1.3731	1.3617	—	0.0114	—	1.3190	1.3127	0.0063	1.2709
1½	6	UNC-2A	0.0024	1.4976	1.4794	1.4703	0.0182	0.0273	1.3893	1.3812	0.0081	1.2931
1½	8	N-2A	0.0022	1.4978	1.4828	1.4753	0.0150	0.0225	1.4166	1.4093	0.0073	1.3444
1½	12	UNF-2A	0.0019	1.4981	1.4867	—	0.0114	—	1.4440	1.4376	0.0064	1.3959
1⅝	8	N-2A	0.0022	1.6228	1.6078	1.6003	0.0150	0.0225	1.5416	1.5342	0.0074	1.4694
1¾	5	UNC-2A	0.0027	1.7473	1.7268	1.7165	0.0205	0.0308	1.6174	1.6085	0.0089	1.5019
1¾	8	N-2A	0.0023	1.7477	1.7327	1.7252	0.0150	0.0225	1.6665	1.6590	0.0075	1.5943
1⅞	8	N-2A	0.0023	1.8727	1.8577	1.8502	0.0150	0.0225	1.7915	1.7838	0.0077	1.7193
2	4½	UNC-2A	0.0029	1.9971	1.9751	1.9641	0.0220	0.0330	1.8528	1.8433	0.0095	1.7245
2	8	N-2A	0.0023	1.9977	1.9827	1.9752	0.0150	0.0225	1.9165	1.9087	0.0078	1.8443
2⅛	8	N-2A	0.0024	2.1226	2.1076	2.1001	0.0150	0.0225	2.0414	2.0335	0.0079	1.9692
2¼	4½	UNC-2A	0.0029	2.2471	2.2251	2.2141	0.0220	0.0330	2.1028	2.0931	0.0097	1.9745
2¼	8	N-2A	0.0024	2.2476	2.2326	2.2251	0.0150	0.0225	2.1664	2.1584	0.0080	2.0942
2½	4	UNC-2A	0.0031	2.4969	2.4731	2.4612	0.0238	0.0357	2.3345	2.3241	0.0104	2.1902
2½	8	N-2A	0.0024	2.4976	2.4826	2.4751	0.0150	0.0225	2.4164	2.4082	0.0082	2.3442
2¾	4	UNC-2A	0.0032	2.7468	2.7230	2.7111	0.0238	0.0357	2.5844	2.5739	0.0105	2.4401
2¾	8	N-2A	0.0025	2.7475	2.7325	2.7250	0.0150	0.0225	2.6663	2.6580	0.0083	2.5941
3	4	UNC-2A	0.0032	2.9968	2.9730	2.9611	0.0238	0.0357	2.8344	2.8237	0.0107	2.6901
3	8	N-2A	0.0026	2.9974	2.9824	2.9749	0.0150	0.0225	2.9162	2.9077	0.0085	2.8440
3¼	4	UNC-2A	0.0033	3.2467	3.2229	3.2110	0.0238	0.0357	3.0843	3.0734	0.0109	2.9400
3¼	8	N-2A	0.0026	3.2474	3.2324	3.2249	0.0150	0.0225	3.1662	3.1575	0.0087	3.0940
3½	4	UNC-2A	0.0033	3.4967	3.4729	3.4610	0.0238	0.0357	3.3343	3.3233	0.0110	3.1900
3½	8	N-2A	0.0026	3.4974	3.4824	3.4749	0.0150	0.0225	3.4162	3.4074	0.0088	3.3440
3¾	4	UNC-2A	0.0034	3.7466	3.7228	3.7109	0.0238	0.0357	3.5842	3.5730	0.0112	3.4399
3¾	8	N-2A	0.0027	3.7473	3.7323	3.7248	0.0150	0.0225	3.6661	3.6571	0.0090	3.5939
4	4	UNC-2A	0.0034	3.9966	3.9728	3.9609	0.0238	0.0357	3.8342	3.8229	0.0113	3.6899
4	8	N-2A	0.0027	3.9973	3.9823	3.9748	0.0150	0.0225	3.9161	3.9070	0.0091	3.8439
4¼	8	N-2A	0.0028	4.2472	4.2322	4.2247	0.0150	0.0225	4.1660	4.1567	0.0093	4.0938
4½	8	N-2A	0.0028	4.4972	4.4822	4.4747	0.0150	0.0225	4.4160	4.4066	0.0094	4.3438
4¾	8	N-2A	0.0029	4.7471	4.7321	4.7246	0.0150	0.0225	4.6659	4.6564	0.0095	4.5937
5	8	N-2A	0.0029	4.9971	4.9821	4.9746	0.0150	0.0225	4.9159	4.9062	0.0097	4.8437
5¼	8	N-2A	0.0029	5.2471	5.2321	5.2246	0.0150	0.0225	5.1659	5.1561	0.0098	5.0937
5½	8	N-2A	0.0030	5.4970	5.4820	5.4745	0.0150	0.0225	5.4158	5.4059	0.0099	5.3436
5¾	8	N-2A	0.0030	5.7470	5.7320	5.7245	0.0150	0.0225	5.6658	5.6558	0.0100	5.5936
6	8	N-2A	0.0030	5.9970	5.9820	5.9745	0.0150	0.0225	5.9158	5.9056	0.0102	5.8436

[a] British: Effective Diameter.
[b] See Fig. 1.
[c] Maximum limits are increased by the amount of the allowance for threads which are electroplated or have coatings of similar thicknesses. Where the allowance is not sufficient for the required thickness of plating or coating, special provisions are necessary.
[d] For semi-finished and finished screws and bolts, threaded portion only.
[e] For unfinished hot-rolled material, threaded portion only.

TABLE 11—*Class 3A, External Threads—UNC, UNF, NC, and NF Series*

DESIGNATION			EXTERNAL-THREAD LIMITS OF SIZE							
				Major diameter			Pitch diameter[a]			
				Limits		Tolerance	Limits		Tolerance	Minor diameter[b]
Size	Threads per inch	Thread symbol	Allowance	Max	Min		Max	Min		
1/4	20	UNC-3A	0.0000	0.2500	0.2419	0.0081	0.2175	0.2147	0.0028	0.1887
1/4	28	UNF-3A	0.0000	0.2500	0.2435	0.0065	0.2268	0.2243	0.0025	0.2062
5/16	18	UNC-3A	0.0000	0.3125	0.3038	0.0087	0.2764	0.2734	0.0030	0.2443
5/16	24	UNF-3A	0.0000	0.3125	0.3053	0.0072	0.2854	0.2827	0.0027	0.2614
3/8	16	UNC-3A	0.0000	0.3750	0.3656	0.0094	0.3344	0.3311	0.0033	0.2983
3/8	24	UNF-3A	0.0000	0.3750	0.3678	0.0072	0.3479	0.3450	0.0029	0.3239
7/16	14	UNC-3A	0.0000	0.4375	0.4272	0.0103	0.3911	0.3876	0.0035	0.3499
7/16	20	UNF-3A	0.0000	0.4375	0.4294	0.0081	0.4050	0.4019	0.0031	0.3762
1/2	13	NC-3A	0.0000	0.5000	0.4891	0.0109	0.4500	0.4463	0.0037	0.4056
1/2	12	UNC-3A	0.0000	0.5000	0.4886	0.0114	0.4459	0.4421	0.0038	0.3978
1/2	20	UNF-3A	0.0000	0.5000	0.4919	0.0081	0.4675	0.4643	0.0032	0.4387
9/16	12	UNC-3A	0.0000	0.5625	0.5511	0.0114	0.5084	0.5045	0.0039	0.4603
9/16	18	UNF-3A	0.0000	0.5625	0.5538	0.0087	0.5264	0.5230	0.0034	0.4943
5/8	11	UNC-3A	0.0000	0.6250	0.6129	0.0121	0.5660	0.5619	0.0041	0.5135
5/8	18	UNF-3A	0.0000	0.6250	0.6163	0.0087	0.5889	0.5854	0.0035	0.5568
3/4	10	UNC-3A	0.0000	0.7500	0.7371	0.0129	0.6850	0.6806	0.0044	0.6273
3/4	16	UNF-3A	0.0000	0.7500	0.7406	0.0094	0.7094	0.7056	0.0038	0.6733
7/8	9	UNC-3A	0.0000	0.8750	0.8611	0.0139	0.8028	0.7981	0.0047	0.7387
7/8	14	UNF-3A	0.0000	0.8750	0.8647	0.0103	0.8286	0.8245	0.0041	0.7874
1	8	UNC-3A	0.0000	1.0000	0.9850	0.0150	0.9188	0.9137	0.0051	0.8466
1	12	UNF-3A	0.0000	1.0000	0.9886	0.0114	0.9459	0.9415	0.0044	0.8978
1	14	NF-3A	0.0000	1.0000	0.9897	0.0103	0.9536	0.9494	0.0042	0.9124
1 1/8	7	UNC-3A	0.0000	1.1250	1.1086	0.0164	1.0322	1.0268	0.0054	0.9497
1 1/8	12	UNF-3A	0.0000	1.1250	1.1136	0.0114	1.0709	1.0664	0.0045	1.0228
1 1/4	7	UNC-3A	0.0000	1.2500	1.2336	0.0164	1.1572	1.1517	0.0055	1.0747
1 1/4	12	UNF-3A	0.0000	1.2500	1.2386	0.0114	1.1959	1.1913	0.0046	1.1478
1 3/8	6	UNC-3A	0.0000	1.3750	1.3568	0.0182	1.2667	1.2607	0.0060	1.1705
1 3/8	12	UNF-3A	0.0000	1.3750	1.3636	0.0114	1.3209	1.3162	0.0047	1.2728
1 1/2	6	UNC-3A	0.0000	1.5000	1.4818	0.0182	1.3917	1.3856	0.0061	1.2955
1 1/2	12	UNF-3A	0.0000	1.5000	1.4886	0.0114	1.4459	1.4411	0.0048	1.3978
1 3/4	5	UNC-3A	0.0000	1.7500	1.7295	0.0205	1.6201	1.6134	0.0067	1.5046
2	4 1/2	UNC-3A	0.0000	2.0000	1.9780	0.0220	1.8557	1.8486	0.0071	1.7274
2 1/4	4 1/2	UNC-3A	0.0000	2.2500	2.2280	0.0220	2.1057	2.0984	0.0073	1.9774
2 1/2	4	UNC-3A	0.0000	2.5000	2.4762	0.0238	2.3376	2.3298	0.0078	2.1933
2 3/4	4	UNC-3A	0.0000	2.7500	2.7262	0.0238	2.5876	2.5797	0.0079	2.4433
3	4	UNC-3A	0.0000	3.0000	2.9762	0.0238	2.8376	2.8296	0.0080	2.6933
3 1/4	4	UNC-3A	0.0000	3.2500	3.2262	0.0238	3.0876	3.0794	0.0082	2.9433
3 1/2	4	UNC-3A	0.0000	3.5000	3.4762	0.0238	3.3376	3.3293	0.0083	3.1933
3 3/4	4	UNC-3A	0.0000	3.7500	3.7262	0.0238	3.5876	3.5792	0.0084	3.4433
4	4	UNC-3A	0.0000	4.0000	3.9762	0.0238	3.8376	3.8291	0.0085	3.6933

[a] British: Effective Diameter.
[b] See Fig. 1.

TABLE 12—*Class 1B, Internal Threads—UNC, UNF, NC, and NF Series*

DESIGNATION			INTERNAL-THREAD LIMITS OF SIZE						
			Minor diameter			Pitch diameter[a]			Major diameter
			Limits		Tolerance	Limits		Tolerance	
Size	Threads per inch	Thread symbol	Min	Max		Min	Max		Min
¼	20	UNC-1B	0.1959	0.2067	0.0108	0.2175	0.2248	0.0073	0.2500
¼	28	UNF-1B	0.2113	0.2190	0.0077	0.2268	0.2333	0.0065	0.2500
5/16	18	UNC-1B	0.2524	0.2630	0.0106	0.2764	0.2843	0.0079	0.3125
5/16	24	UNF-1B	0.2674	0.2754	0.0080	0.2854	0.2925	0.0071	0.3125
3/8	16	UNC-1B	0.3073	0.3182	0.0109	0.3344	0.3429	0.0085	0.3750
3/8	24	UNF-1B	0.3299	0.3372	0.0073	0.3479	0.3553	0.0074	0.3750
7/16	14	UNC-1B	0.3602	0.3717	0.0115	0.3911	0.4003	0.0092	0.4375
7/16	20	UNF-1B	0.3834	0.3916	0.0082	0.4050	0.4131	0.0081	0.4375
½	13	NC-1B	0.4167	0.4284	0.0117	0.4500	0.4597	0.0097	0.5000
½	12	UNC-1B	0.4098	0.4223	0.0125	0.4459	0.4559	0.0100	0.5000
½	20	UNF-1B	0.4459	0.4537	0.0078	0.4675	0.4759	0.0084	0.5000
9/16	12	UNC-1B	0.4723	0.4843	0.0120	0.5084	0.5186	0.0102	0.5625
9/16	18	UNF-1B	0.5024	0.5106	0.0082	0.5264	0.5353	0.0089	0.5625
5/8	11	UNC-1B	0.5266	0.5391	0.0125	0.5660	0.5767	0.0107	0.6250
5/8	18	UNF-1B	0.5649	0.5730	0.0081	0.5889	0.5980	0.0091	0.6250
¾	10	UNC-1B	0.6417	0.6545	0.0128	0.6850	0.6965	0.0115	0.7500
¾	16	UNF-1B	0.6823	0.6908	0.0085	0.7094	0.7192	0.0098	0.7500
7/8	9	UNC-1B	0.7547	0.7681	0.0134	0.8028	0.8151	0.0123	0.8750
7/8	14	UNF-1B	0.7977	0.8068	0.0091	0.8286	0.8392	0.0106	0.8750
1	8	UNC-1B	0.8647	0.8797	0.0150	0.9188	0.9320	0.0132	1.0000
1	12	UNF-1B	0.9098	0.9198	0.0100	0.9459	0.9573	0.0114	1.0000
1	14	NF-1B	0.9227	0.9315	0.0088	0.9536	0.9645	0.0109	1.0000
1⅛	7	UNC-1B	0.9704	0.9875	0.0171	1.0322	1.0463	0.0141	1.1250
1⅛	12	UNF-1B	1.0348	1.0448	0.0100	1.0709	1.0826	0.0117	1.1250
1¼	7	UNC-1B	1.0954	1.1125	0.0171	1.1572	1.1716	0.0144	1.2500
1¼	12	UNF-1B	1.1598	1.1698	0.0100	1.1959	1.2079	0.0120	1.2500
1⅜	6	UNC-1B	1.1946	1.2146	0.0200	1.2667	1.2822	0.0155	1.3750
1⅜	12	UNF-1B	1.2848	1.2948	0.0100	1.3209	1.3332	0.0123	1.3750
1½	6	UNC-1B	1.3196	1.3396	0.0200	1.3917	1.4075	0.0158	1.5000
1½	12	UNF-1B	1.4098	1.4198	0.0100	1.4459	1.4584	0.0125	1.5000
1¾	5	UNC-1B	1.5335	1.5575	0.0240	1.6201	1.6375	0.0174	1.7500
2	4½	UNC-1B	1.7594	1.7861	0.0267	1.8557	1.8743	0.0186	2.0000
2¼	4½	UNC-1B	2.0094	2.0361	0.0267	2.1057	2.1247	0.0190	2.2500
2½	4	UNC-1B	2.2294	2.2594	0.0300	2.3376	2.3578	0.0202	2.5000
2¾	4	UNC-1B	2.4794	2.5094	0.0300	2.5876	2.6082	0.0206	2.7500
3	4	UNC-1B	2.7294	2.7594	0.0300	2.8376	2.8585	0.0209	3.0000
3¼	4	UNC-1B	2.9794	3.0094	0.0300	3.0876	3.1088	0.0212	3.2500
3½	4	UNC-1B	3.2294	3.2594	0.0300	3.3376	3.3591	0.0215	3.5000
3¾	4	UNC-1B	3.4794	3.5094	0.0300	3.5876	3.6094	0.0218	3.7500
4	4	UNC-1B	3.7294	3.7594	0.0300	3.8376	3.8597	0.0221	4.0000

[a] British: Effective Diameter.

TABLE 13a—*Class 2B, Internal Threads—UNC, UNF, NC, NF, and 8N Series*

DESIGNATION			INTERNAL-THREAD LIMITS OF SIZE						
			Minor diameter			Pitch diameter[a]			Major diameter
Size	Threads per inch	Thread symbol	Limits		Tolerance	Limits		Tolerance	
			Min	Max		Min	Max		Min
0 (0.060)	80	NF-2B	0.0465	0.0514	0.0049	0.0519	0.0542	0.0023	0.0600
1 (0.073)	64	NC-2B	0.0561	0.0623	0.0062	0.0629	0.0655	0.0026	0.0730
1 (0.073)	72	NF-2B	0.0580	0.0635	0.0055	0.0640	0.0665	0.0025	0.0730
2 (0.086)	56	NC-2B	0.0667	0.0737	0.0070	0.0744	0.0772	0.0028	0.0860
2 (0.086)	64	NF-2B	0.0691	0.0753	0.0062	0.0759	0.0786	0.0027	0.0860
3 (0.099)	48	NC-2B	0.0764	0.0845	0.0081	0.0855	0.0885	0.0030	0.0990
3 (0.099)	56	NF-2B	0.0797	0.0865	0.0068	0.0874	0.0902	0.0028	0.0990
4 (0.112)	40	NC-2B	0.0849	0.0939	0.0090	0.0958	0.0991	0.0033	0.1120
4 (0.112)	48	NF-2B	0.0894	0.0968	0.0074	0.0985	0.1016	0.0031	0.1120
5 (0.125)	40	NC-2B	0.0979	0.1062	0.0083	0.1088	0.1121	0.0033	0.1250
5 (0.125)	44	NF-2B	0.1004	0.1079	0.0075	0.1102	0.1134	0.0032	0.1250
6 (0.138)	32	NC-2B	0.1042	0.1140	0.0098	0.1177	0.1214	0.0037	0.1380
6 (0.138)	40	NF-2B	0.1109	0.1186	0.0077	0.1218	0.1252	0.0034	0.1380
8 (0.164)	32	NC-2B	0.1302	0.1389	0.0087	0.1437	0.1475	0.0038	0.1640
8 (0.164)	36	NF-2B	0.1339	0.1416	0.0077	0.1460	0.1496	0.0036	0.1640
10 (0.190)	24	NC-2B	0.1449	0.1555	0.0106	0.1629	0.1672	0.0043	0.1900
10 (0.190)	32	NF-2B	0.1562	0.1641	0.0079	0.1697	0.1736	0.0039	0.1900
12 (0.216)	24	NC-2B	0.1709	0.1807	0.0098	0.1889	0.1933	0.0044	0.2160
12 (0.216)	28	NF-2B	0.1773	0.1857	0.0084	0.1928	0.1970	0.0042	0.2160
1/4	20	UNC-2B	0.1959	0.2067	0.0108	0.2175	0.2223	0.0048	0.2500
1/4	28	UNF-2B	0.2113	0.2190	0.0077	0.2268	0.2311	0.0043	0.2500
5/16	18	UNC-2B	0.2524	0.2630	0.0106	0.2764	0.2817	0.0053	0.3125
5/16	24	UNF-2B	0.2674	0.2754	0.0080	0.2854	0.2902	0.0048	0.3125
3/8	16	UNC-2B	0.3073	0.3182	0.0109	0.3344	0.3401	0.0057	0.3750
3/8	24	UNF-2B	0.3299	0.3372	0.0073	0.3479	0.3528	0.0049	0.3750
7/16	14	UNC-2B	0.3602	0.3717	0.0115	0.3911	0.3972	0.0061	0.4375
7/16	20	UNF-2B	0.3834	0.3916	0.0082	0.4050	0.4104	0.0054	0.4375
1/2	13	NC-2B	0.4167	0.4284	0.0117	0.4500	0.4565	0.0065	0.5000
1/2	12	UNC-2B	0.4098	0.4223	0.0125	0.4459	0.4525	0.0066	0.5000
1/2	20	UNF-2B	0.4459	0.4537	0.0078	0.4675	0.4731	0.0056	0.5000
9/16	12	UNC-2B	0.4723	0.4843	0.0120	0.5084	0.5152	0.0068	0.5625
9/16	18	UNF-2B	0.5024	0.5106	0.0082	0.5264	0.5323	0.0059	0.5625
5/8	11	UNC-2B	0.5266	0.5391	0.0125	0.5660	0.5732	0.0072	0.6250
5/8	18	UNF-2B	0.5649	0.5730	0.0081	0.5889	0.5949	0.0060	0.6250
3/4	10	UNC-2B	0.6417	0.6545	0.0128	0.6850	0.6927	0.0077	0.7500
3/4	16	UNF-2B	0.6823	0.6908	0.0085	0.7094	0.7159	0.0065	0.7500
7/8	9	UNC-2B	0.7547	0.7681	0.0134	0.8028	0.8110	0.0082	0.8750
7/8	14	UNF-2B	0.7977	0.8068	0.0091	0.8286	0.8356	0.0070	0.8750
1	8	UNC-2B	0.8647	0.8797	0.0150	0.9188	0.9276	0.0088	1.0000
1	12	UNF-2B	0.9098	0.9198	0.0100	0.9459	0.9535	0.0076	1.0000
1	14	NF-2B	0.9227	0.9315	0.0088	0.9536	0.9609	0.0073	1.0000
1 1/8	7	UNC-2B	0.9704	0.9875	0.0171	1.0322	1.0416	0.0094	1.1250
1 1/8	8	N-2B	0.9897	1.0047	0.0150	1.0438	1.0528	0.0090	1.1250
1 1/8	12	UNF-2B	1.0348	1.0448	0.0100	1.0709	1.0787	0.0078	1.1250

[a] British: Effective Diameter.

TABLE 13b—*Class 2B, Internal Threads—UNC, UNF, NC, NF, and 8N Series*

DESIGNATION			INTERNAL-THREAD LIMITS OF SIZE						
			Minor diameter			Pitch diameter[a]			Major diameter
			Limits		Tolerance	Limits		Tolerance	
Size	Threads per inch	Thread symbol	Min	Max		Min	Max		Min
1¼	7	UNC-2B	1.0954	1.1125	0.0171	1.1572	1.1668	0.0096	1.2500
1¼	8	N-2B	1.1147	1.1297	0.0150	1.1688	1.1780	0.0092	1.2500
1¼	12	UNF-2B	1.1598	1.1698	0.0100	1.1959	1.2039	0.0080	1.2500
1⅜	6	UNC-2B	1.1946	1.2146	0.0200	1.2667	1.2771	0.0104	1.3750
1⅜	8	N-2B	1.2397	1.2547	0.0150	1.2938	1.3031	0.0093	1.3750
1⅜	12	UNF-2B	1.2848	1.2948	0.0100	1.3209	1.3291	0.0082	1.3750
1½	6	UNC-2B	1.3196	1.3396	0.0200	1.3917	1.4022	0.0105	1.5000
1½	8	N-2B	1.3647	1.3797	0.0150	1.4188	1.4283	0.0095	1.5000
1½	12	UNF-2B	1.4098	1.4198	0.0100	1.4459	1.4542	0.0083	1.5000
1⅝	8	N-2B	1.4897	1.5047	0.0150	1.5438	1.5535	0.0097	1.6250
1¾	5	UNC-2B	1.5335	1.5575	0.0240	1.6201	1.6317	0.0116	1.7500
1¾	8	N-2B	1.6147	1.6297	0.0150	1.6688	1.6786	0.0098	1.7500
1⅞	8	N-2B	1.7397	1.7547	0.0150	1.7938	1.8038	0.0100	1.8750
2	4½	UNC-2B	1.7594	1.7861	0.0267	1.8557	1.8681	0.0124	2.0000
2	8	N-2B	1.8647	1.8797	0.0150	1.9188	1.9289	0.0101	2.0000
2⅛	8	N-2B	1.9897	2.0047	0.0150	2.0438	2.0540	0.0102	2.1250
2¼	4½	UNC-2B	2.0094	2.0361	0.0267	2.1057	2.1183	0.0126	2.2500
2¼	8	N-2B	2.1147	2.1297	0.0150	2.1688	2.1792	0.0104	2.2500
2½	4	UNC-2B	2.2294	2.2594	0.0300	2.3376	2.3511	0.0135	2.5000
2½	8	N-2B	2.3647	2.3797	0.0150	2.4188	2.4294	0.0106	2.5000
2¾	4	UNC-2B	2.4794	2.5094	0.0300	2.5876	2.6013	0.0137	2.7500
2¾	8	N-2B	2.6147	2.6297	0.0150	2.6688	2.6796	0.0108	2.7500
3	4	UNC-2B	2.7294	2.7594	0.0300	2.8376	2.8515	0.0139	3.0000
3	8	N-2B	2.8647	2.8797	0.0150	2.9188	2.9299	0.0111	3.0000
3¼	4	UNC-2B	2.9794	3.0094	0.0300	3.0876	3.1017	0.0141	3.2500
3¼	8	N-2B	3.1147	3.1297	0.0150	3.1688	3.1801	0.0113	3.2500
3½	4	UNC-2B	3.2294	3.2594	0.0300	3.3376	3.3519	0.0143	3.5000
3½	8	N-2B	3.3647	3.3797	0.0150	3.4188	3.4303	0.0115	3.5000
3¾	4	UNC-2B	3.4794	3.5094	0.0300	3.5876	3.6021	0.0145	3.7500
3¾	8	N-2B	3.6147	3.6297	0.0150	3.6688	3.6805	0.0117	3.7500
4	4	UNC-2B	3.7294	3.7594	0.0300	3.8376	3.8523	0.0147	4.0000
4	8	N-2B	3.8647	3.8797	0.0150	3.9188	3.9307	0.0119	4.0000
4¼	8	N-2B	4.1147	4.1297	0.0150	4.1688	4.1809	0.0121	4.2500
4½	8	N-2B	4.3647	4.3797	0.0150	4.4188	4.4310	0.0122	4.5000
4¾	8	N-2B	4.6147	4.6297	0.0150	4.6688	4.6812	0.0124	4.7500
5	8	N-2B	4.8647	4.8797	0.0150	4.9188	4.9314	0.0126	5.0000
5¼	8	N-2B	5.1147	5.1297	0.0150	5.1688	5.1815	0.0127	5.2500
5½	8	N-2B	5.3647	5.3797	0.0150	5.4188	5.4317	0.0129	5.5000
5¾	8	N-2B	5.6147	5.6297	0.0150	5.6688	5.6818	0.0130	5.7500
6	8	N-2B	5.8647	5.8797	0.0150	5.9188	5.9320	0.0132	6.0000

[a] British: Effective Diameter.

TABLE 14—*Class 3B, Internal Threads—UNC, UNF, NC, and NF Series*

DESIGNATION			INTERNAL-THREAD LIMITS OF SIZE						
			Minor diameter			Pitch diameter[a]			Major diameter
			Limits		Tolerance	Limits		Tolerance	
Size	Threads per inch	Thread symbol	Min	Max		Min	Max		Min
¼	20	UNC-3B	0.1959	0.2067	0.0108	0.2175	0.2211	0.0036	0.2500
¼	28	UNF-3B	0.2113	0.2190	0.0077	0.2268	0.2300	0.0032	0.2500
5/16	18	UNC-3B	0.2524	0.2630	0.0106	0.2764	0.2803	0.0039	0.3125
5/16	24	UNF-3B	0.2674	0.2754	0.0080	0.2854	0.2890	0.0036	0.3125
⅜	16	UNC-3B	0.3073	0.3182	0.0109	0.3344	0.3387	0.0043	0.3750
⅜	24	UNF-3B	0.3299	0.3372	0.0073	0.3479	0.3516	0.0037	0.3750
7/16	14	UNC-3B	0.3602	0.3717	0.0115	0.3911	0.3957	0.0046	0.4375
7/16	20	UNF-3B	0.3834	0.3916	0.0082	0.4050	0.4091	0.0041	0.4375
½	13	NC-3B	0.4167	0.4284	0.0117	0.4500	0.4548	0.0048	0.5000
½	12	UNC-3B	0.4098	0.4223	0.0125	0.4459	0.4509	0.0050	0.5000
½	20	UNF-3B	0.4459	0.4537	0.0078	0.4675	0.4717	0.0042	0.5000
9/16	12	UNC-3B	0.4723	0.4843	0.0120	0.5084	0.5135	0.0051	0.5625
9/16	18	UNF-3B	0.5024	0.5106	0.0082	0.5264	0.5308	0.0044	0.5625
⅝	11	UNC-3B	0.5266	0.5391	0.0125	0.5660	0.5714	0.0054	0.6250
⅝	18	UNF-3B	0.5649	0.5730	0.0081	0.5889	0.5934	0.0045	0.6250
¾	10	UNC-3B	0.6417	0.6545	0.0128	0.6850	0.6907	0.0057	0.7500
¾	16	UNF-3B	0.6823	0.6908	0.0085	0.7094	0.7143	0.0049	0.7500
⅞	9	UNC-3B	0.7547	0.7681	0.0134	0.8028	0.8089	0.0061	0.8750
⅞	14	UNF-3B	0.7977	0.8068	0.0091	0.8286	0.8339	0.0053	0.8750
1	8	UNC-3B	0.8647	0.8797	0.0150	0.9188	0.9254	0.0066	1.0000
1	12	UNF-3B	0.9098	0.9198	0.0100	0.9459	0.9516	0.0057	1.0000
1	14	NF-3B	0.9227	0.9315	0.0088	0.9536	0.9590	0.0054	1.0000
1⅛	7	UNC-3B	0.9704	0.9875	0.0171	1.0322	1.0393	0.0071	1.1250
1⅛	12	UNF-3B	1.0348	1.0448	0.0100	1.0709	1.0768	0.0059	1.1250
1¼	7	UNC-3B	1.0954	1.1125	0.0171	1.1572	1.1644	0.0072	1.2500
1¼	12	UNF-3B	1.1598	1.1698	0.0100	1.1959	1.2019	0.0060	1.2500
1⅜	6	UNC-3B	1.1946	1.2146	0.0200	1.2667	1.2745	0.0078	1.3750
1⅜	12	UNF-3B	1.2848	1.2948	0.0100	1.3209	1.3270	0.0061	1.3750
1½	6	UNC-3B	1.3196	1.3396	0.0200	1.3917	1.3996	0.0079	1.5000
1½	12	UNF-3B	1.4098	1.4198	0.0100	1.4459	1.4522	0.0063	1.5000
1¾	5	UNC-3B	1.5335	1.5575	0.0240	1.6201	1.6288	0.0087	1.7500
2	4½	UNC-3B	1.7594	1.7861	0.0267	1.8557	1.8650	0.0093	2.0000
2¼	4½	UNC-3B	2.0094	2.0361	0.0267	2.1057	2.1152	0.0095	2.2500
2½	4	UNC-3B	2.2294	2.2594	0.0300	2.3376	2.3477	0.0101	2.5000
2¾	4	UNC-3B	2.4794	2.5094	0.0300	2.5876	2.5979	0.0103	2.7500
3	4	UNC-3B	2.7294	2.7594	0.0300	2.8376	2.8480	0.0104	3.0000
3¼	4	UNC-3B	2.9794	3.0094	0.0300	3.0876	3.0982	0.0106	3.2500
3½	4	UNC-3B	3.2294	3.2594	0.0300	3.3376	3.3484	0.0108	3.5000
3¾	4	UNC-3B	3.4794	3.5094	0.0300	3.5876	3.5985	0.0109	3.7500
4	4	UNC-3B	3.7294	3.7594	0.0300	3.8376	3.8487	0.0111	4.0000

[a] British: Effective Diameter.

TABLE 15a—*Class 2, External and Internal Threads—NC, NF, and 8N Series*

DESIGNATION			LIMITS OF SIZE									
			External threads						Internal threads			
Size	Threads per inch	Thread symbol	Major diameter			Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
			Max	Min[b]	Min[c]	Max	Min		Min	Max	Min	Max	Min
0 (0.060)	80	NF-2	0.0600	0.0566	—	0.0519	0.0502	0.0447	0.0465	0.0514	0.0519	0.0536	0.0600
1 (0.073)	64	NC-2	0.0730	0.0692	0.0678	0.0629	0.0610	0.0538	0.0561	0.0623	0.0629	0.0648	0.0730
1 (0.073)	72	NF-2	0.0730	0.0694	—	0.0640	0.0622	0.0560	0.0580	0.0634	0.0640	0.0658	0.0730
2 (0.086)	56	NC-2	0.0860	0.0820	0.0804	0.0744	0.0724	0.0641	0.0667	0.0737	0.0744	0.0764	0.0860
2 (0.086)	64	NF-2	0.0860	0.0822	—	0.0759	0.0740	0.0668	0.0691	0.0746	0.0759	0.0778	0.0860
3 (0.099)	48	NC-2	0.0990	0.0946	0.0928	0.0855	0.0833	0.0734	0.0764	0.0841	0.0855	0.0877	0.0990
3 (0.099)	56	NF-2	0.0990	0.0950	—	0.0874	0.0854	0.0771	0.0797	0.0856	0.0874	0.0894	0.0990
4 (0.112)	40	NC-2	0.1120	0.1072	0.1052	0.0958	0.0934	0.0813	0.0849	0.0938	0.0958	0.0982	0.1120
4 (0.112)	48	NF-2	0.1120	0.1076	—	0.0985	0.0963	0.0864	0.0894	0.0960	0.0985	0.1007	0.1120
5 (0.125)	40	NC-2	0.1250	0.1202	0.1182	0.1088	0.1064	0.0943	0.0979	0.1062	0.1088	0.1112	0.1250
5 (0.125)	44	NF-2	0.1250	0.1204	—	0.1102	0.1079	0.0971	0.1004	0.1068	0.1102	0.1125	0.1250
6 (0.138)	32	NC-2	0.1380	0.1326	0.1304	0.1177	0.1150	0.0997	0.1042	0.1145	0.1177	0.1204	0.1380
6 (0.138)	40	NF-2	0.1380	0.1332	—	0.1218	0.1194	0.1073	0.1109	0.1179	0.1218	0.1242	0.1380
8 (0.164)	32	NC-2	0.1640	0.1586	0.1564	0.1437	0.1410	0.1257	0.1302	0.1384	0.1437	0.1464	0.1640
8 (0.164)	36	NF-2	0.1640	0.1590	—	0.1460	0.1435	0.1299	0.1339	0.1402	0.1460	0.1485	0.1640
10 (0.190)	24	NC-2	0.1900	0.1834	0.1808	0.1629	0.1596	0.1389	0.1449	0.1559	0.1629	0.1662	0.1900
10 (0.190)	32	NF-2	0.1900	0.1846	—	0.1697	0.1670	0.1517	0.1562	0.1624	0.1697	0.1724	0.1900
12 (0.216)	24	NC-2	0.2160	0.2094	0.2068	0.1889	0.1856	0.1649	0.1709	0.1801	0.1889	0.1922	0.2160
12 (0.216)	28	NF-2	0.2160	0.2098	—	0.1928	0.1897	0.1722	0.1773	0.1835	0.1928	0.1959	0.2160
1/4	20	NC-2	0.2500	0.2428	0.2398	0.2175	0.2139	0.1887	0.1959	0.2060	0.2175	0.2211	0.2500
1/4	28	NF-2	0.2500	0.2438	—	0.2268	0.2237	0.2062	0.2113	0.2173	0.2268	0.2299	0.2500
5/16	18	NC-2	0.3125	0.3043	0.3011	0.2764	0.2723	0.2443	0.2524	0.2630	0.2764	0.2805	0.3125
5/16	24	NF-2	0.3125	0.3059	—	0.2854	0.2821	0.2614	0.2674	0.2739	0.2854	0.2887	0.3125
3/8	16	NC-2	0.3750	0.3660	0.3624	0.3344	0.3299	0.2983	0.3073	0.3184	0.3344	0.3389	0.3750
3/8	24	NF-2	0.3750	0.3684	—	0.3479	0.3446	0.3239	0.3299	0.3364	0.3479	0.3512	0.3750
7/16	14	NC-2	0.4375	0.4277	0.4235	0.3911	0.3862	0.3499	0.3602	0.3721	0.3911	0.3960	0.4375
7/16	20	NF-2	0.4375	0.4303	—	0.4050	0.4014	0.3762	0.3834	0.3906	0.4050	0.4086	0.4375
1/2	13	NC-2	0.5000	0.4896	0.4852	0.4500	0.4448	0.4056	0.4167	0.4290	0.4500	0.4552	0.5000
1/2	20	NF-2	0.5000	0.4928	—	0.4675	0.4639	0.4387	0.4459	0.4531	0.4675	0.4711	0.5000
9/16	12	NC-2	0.5625	0.5513	0.5467	0.5084	0.5028	0.4603	0.4723	0.4850	0.5084	0.5140	0.5625
9/16	18	NF-2	0.5625	0.5543	—	0.5264	0.5223	0.4943	0.5024	0.5100	0.5264	0.5305	0.5625
5/8	11	NC-2	0.6250	0.6132	0.6080	0.5660	0.5601	0.5135	0.5266	0.5397	0.5660	0.5719	0.6250
5/8	18	NF-2	0.6250	0.6168	—	0.5889	0.5848	0.5568	0.5649	0.5725	0.5889	0.5930	0.6250
3/4	10	NC-2	0.7500	0.7372	0.7316	0.6850	0.6786	0.6273	0.6417	0.6553	0.6850	0.6914	0.7500
3/4	16	NF-2	0.7500	0.7410	—	0.7094	0.7049	0.6733	0.6823	0.6903	0.7094	0.7139	0.7500
7/8	9	NC-2	0.8750	0.8610	0.8550	0.8028	0.7958	0.7387	0.7547	0.7689	0.8028	0.8098	0.8750
7/8	14	NF-2	0.8750	0.8652	—	0.8286	0.8237	0.7874	0.7977	0.8062	0.8286	0.8335	0.8750
1	8	NC-2	1.0000	0.9848	0.9778	0.9188	0.9112	0.8466	0.8647	0.8795	0.9188	0.9264	1.0000
1	14	NF-2	1.0000	0.9902	—	0.9536	0.9487	0.9124	0.9227	0.9312	0.9536	0.9585	1.0000
1 1/8	7	NC-2	1.1250	1.1080	1.1002	1.0322	1.0237	0.9497	0.9704	0.9858	1.0322	1.0407	1.1250
1 1/8	8	N-2	1.1250	1.1098	1.1028	1.0438	1.0359	0.9716	0.9897	1.0045	1.0438	1.0517	1.1250
1 1/8	12	NF-2	1.1250	1.1138	—	1.0709	1.0653	1.0228	1.0348	1.0438	1.0709	1.0765	1.1250

[a] See Fig. 1.
[b] For semi-finished and finished screws and bolts, threaded portion only.
[c] For unfinished hot-rolled material, threaded portion only.

TABLE 15b—*Class 2, External and Internal Threads—NC, NF, and 8N Series*

DESIGNATION			LIMITS OF SIZE										
			External threads						Internal threads				
Size	Threads per inch	Thread symbol	Major diameter			Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
			Max	Min[b]	Min[c]	Max	Min		Min	Max	Min	Max	Min
1¼	7	NC-2	1.2500	1.2330	1.2252	1.1572	1.1487	1.0747	1.0954	1.1108	1.1572	1.1657	1.2500
1¼	8	N-2	1.2500	1.2348	1.2278	1.1688	1.1605	1.0966	1.1147	1.1295	1.1688	1.1771	1.2500
1¼	12	NF-2	1.2500	1.2388	—	1.1959	1.1903	1.1478	1.1598	1.1688	1.1959	1.2015	1.2500
1⅜	6	NC-2	1.3750	1.3548	1.3460	1.2667	1.2566	1.1705	1.1946	1.2126	1.2667	1.2768	1.3750
1⅜	8	N-2	1.3750	1.3598	1.3528	1.2938	1.2852	1.2216	1.2397	1.2545	1.2938	1.3024	1.3750
1⅜	12	NF-2	1.3750	1.3638	—	1.3209	1.3153	1.2728	1.2848	1.2938	1.3209	1.3265	1.3750
1½	6	NC-2	1.5000	1.4798	1.4710	1.3917	1.3816	1.2955	1.3196	1.3376	1.3917	1.4018	1.5000
1½	8	N-2	1.5000	1.4848	1.4778	1.4188	1.4098	1.3466	1.3647	1.3795	1.4188	1.4278	1.5000
1½	12	NF-2	1.5000	1.4888	—	1.4459	1.4403	1.3978	1.4098	1.4188	1.4459	1.4515	1.5000
1⅝	8	N-2	1.6250	1.6098	1.6028	1.5438	1.5345	1.4716	1.4897	1.5045	1.5438	1.5531	1.6250
1¾	5	NC-2	1.7500	1.7268	1.7162	1.6201	1.6085	1.5046	1.5335	1.5551	1.6201	1.6317	1.7500
1¾	8	N-2	1.7500	1.7348	1.7278	1.6688	1.6591	1.5966	1.6147	1.6295	1.6688	1.6785	1.7500
1⅞	8	N-2	1.8750	1.8598	1.8528	1.7938	1.7838	1.7216	1.7397	1.7545	1.7938	1.8038	1.8750
2	4½	NC-2	2.0000	1.9746	1.9632	1.8557	1.8430	1.7274	1.7594	1.7835	1.8557	1.8684	2.0000
2	8	N-2	2.0000	1.9848	1.9778	1.9188	1.9084	1.8466	1.8647	1.8795	1.9188	1.9292	2.0000
2⅛	8	N-2	2.1250	2.1098	2.1028	2.0438	2.0331	1.9716	1.9897	2.0045	2.0438	2.0545	2.1250
2¼	4½	NC-2	2.2500	2.2246	2.2132	2.1057	2.0930	1.9774	2.0094	2.0335	2.1057	2.1184	2.2500
2¼	8	N-2	2.2500	2.2348	2.2278	2.1688	2.1578	2.0966	2.1147	2.1295	2.1688	2.1798	2.2500
2½	4	NC-2	2.5000	2.4720	2.4592	2.3376	2.3236	2.1933	2.2294	2.2564	2.3376	2.3516	2.5000
2½	8	N-2	2.5000	2.4848	2.4778	2.4188	2.4071	2.3466	2.3647	2.3795	2.4188	2.4305	2.5000
2¾	4	NC-2	2.7500	2.7220	2.7092	2.5876	2.5736	2.4433	2.4794	2.5064	2.5876	2.6016	2.7500
2¾	8	N-2	2.7500	2.7348	2.7278	2.6688	2.6564	2.5966	2.6147	2.6295	2.6688	2.6812	2.7500
3	4	NC-2	3.0000	2.9720	2.9592	2.8376	2.8236	2.6933	2.7294	2.7564	2.8376	2.8516	3.0000
3	8	N-2	3.0000	2.9848	2.9778	2.9188	2.9058	2.8466	2.8647	2.8795	2.9188	2.9318	3.0000
3¼	4	NC-2	3.2500	3.2220	3.2092	3.0876	3.0736	2.9433	2.9794	3.0064	3.0876	3.1016	3.2500
3¼	8	N-2	3.2500	3.2348	3.2278	3.1688	3.1556	3.0966	3.1147	3.1295	3.1688	3.1820	3.2500
3½	4	NC-2	3.5000	3.4720	3.4592	3.3376	3.3236	3.1933	3.2294	3.2564	3.3376	3.3516	3.5000
3½	8	N-2	3.5000	3.4848	3.4778	3.4188	3.4055	3.3466	3.3647	3.3795	3.4188	3.4321	3.5000
3¾	4	NC-2	3.7500	3.7220	3.7092	3.5876	3.5736	3.4433	3.4794	3.5064	3.5876	3.6016	3.7500
3¾	8	N-2	3.7500	3.7348	3.7278	3.6688	3.6554	3.5966	3.6147	3.6295	3.6688	3.6822	3.7500
4	4	NC-2	4.0000	3.9720	3.9592	3.8376	3.8236	3.6933	3.7294	3.7564	3.8376	3.8516	4.0000
4	8	N-2	4.0000	3.9848	3.9778	3.9188	3.9053	3.8466	3.8647	3.8795	3.9188	3.9323	4.0000
4¼	8	N-2	4.2500	4.2348	4.2278	4.1688	4.1551	4.0966	4.1147	4.1295	4.1688	4.1825	4.2500
4½	8	N-2	4.5000	4.4848	4.4778	4.4188	4.4050	4.3466	4.3647	4.3795	4.4188	4.4326	4.5000
4¾	8	N-2	4.7500	4.7348	4.7278	4.6688	4.6549	4.5966	4.6147	4.6295	4.6688	4.6827	4.7500
5	8	N-2	5.0000	4.9848	4.9778	4.9188	4.9048	4.8466	4.8647	4.8795	4.9188	4.9328	5.0000
5¼	8	N-2	5.2500	5.2348	5.2278	5.1688	5.1547	5.0966	5.1147	5.1295	5.1688	5.1829	5.2500
5½	8	N-2	5.5000	5.4848	5.4778	5.4188	5.4046	5.3466	5.3647	5.3795	5.4188	5.4330	5.5000
5¾	8	N-2	5.7500	5.7348	5.7278	5.6688	5.6545	5.5966	5.6147	5.6295	5.6688	5.6831	5.7500
6	8	N-2	6.0000	5.9848	5.9778	5.9188	5.9044	5.8466	5.8647	5.8795	5.9188	5.9332	6.0000

[a] See Fig. 1.
[b] For semi-finished and finished screws and bolts, threaded portion only.
[c] For unfinished hot-rolled material, threaded portion only.

TABLE 16a—*Class 3, External and Internal Threads—NC, NF, and 8N Series*

DESIGNATION			LIMITS OF SIZE									
			External threads					Internal threads				
Size	Threads per inch	Thread symbol	Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
			Max	Min	Max	Min		Min	Max	Min	Max	Min
0 (0.060)	80	NF-3	0.0600	0.0566	0.0519	0.0506	0.0447	0.0465	0.0514	0.0519	0.0532	0.0600
1 (0.073)	64	NC-3	0.0730	0.0692	0.0629	0.0615	0.0538	0.0561	0.0623	0.0629	0.0643	0.0730
1 (0.073)	72	NF-3	0.0730	0.0694	0.0640	0.0627	0.0560	0.0580	0.0634	0.0640	0.0653	0.0730
2 (0.086)	56	NC-3	0.0860	0.0820	0.0744	0.0729	0.0641	0.0667	0.0737	0.0744	0.0759	0.0860
2 (0.086)	64	NF-3	0.0860	0.0822	0.0759	0.0745	0.0668	0.0691	0.0746	0.0759	0.0773	0.0860
3 (0.099)	48	NC-3	0.0990	0.0946	0.0855	0.0839	0.0734	0.0764	0.0841	0.0855	0.0871	0.0990
3 (0.099)	56	NF-3	0.0990	0.0950	0.0874	0.0859	0.0771	0.0797	0.0856	0.0874	0.0889	0.0990
4 (0.112)	40	NC-3	0.1120	0.1072	0.0958	0.0941	0.0813	0.0849	0.0938	0.0958	0.0975	0.1120
4 (0.112)	48	NF-3	0.1120	0.1076	0.0985	0.0969	0.0864	0.0894	0.0960	0.0985	0.1001	0.1120
5 (0.125)	40	NC-3	0.1250	0.1202	0.1088	0.1071	0.0943	0.0979	0.1062	0.1088	0.1105	0.1250
5 (0.125)	44	NF-3	0.1250	0.1204	0.1102	0.1086	0.0971	0.1004	0.1068	0.1102	0.1118	0.1250
6 (0.138)	32	NC-3	0.1380	0.1326	0.1177	0.1158	0.0997	0.1042	0.1145	0.1177	0.1196	0.1380
6 (0.138)	40	NF-3	0.1380	0.1332	0.1218	0.1201	0.1073	0.1109	0.1179	0.1218	0.1235	0.1380
8 (0.164)	32	NC-3	0.1640	0.1586	0.1437	0.1418	0.1257	0.1302	0.1384	0.1437	0.1456	0.1640
8 (0.164)	36	NF-3	0.1640	0.1590	0.1460	0.1442	0.1299	0.1339	0.1402	0.1460	0.1478	0.1640
10 (0.190)	24	NC-3	0.1900	0.1834	0.1629	0.1605	0.1389	0.1449	0.1559	0.1629	0.1653	0.1900
10 (0.190)	32	NF-3	0.1900	0.1846	0.1697	0.1678	0.1517	0.1562	0.1624	0.1697	0.1716	0.1900
12 (0.216)	24	NC-3	0.2160	0.2094	0.1889	0.1865	0.1649	0.1709	0.1801	0.1889	0.1913	0.2160
12 (0.216)	28	NF-3	0.2160	0.2098	0.1928	0.1906	0.1722	0.1773	0.1835	0.1928	0.1950	0.2160
1/4	20	NC-3	0.2500	0.2428	0.2175	0.2149	0.1887	0.1959	0.2060	0.2175	0.2201	0.2500
1/4	28	NF-3	0.2500	0.2438	0.2268	0.2246	0.2062	0.2113	0.2173	0.2268	0.2290	0.2500
5/16	18	NC-3	0.3125	0.3043	0.2764	0.2734	0.2443	0.2524	0.2630	0.2764	0.2794	0.3125
5/16	24	NF-3	0.3125	0.3059	0.2854	0.2830	0.2614	0.2674	0.2739	0.2854	0.2878	0.3125
3/8	16	NC-3	0.3750	0.3660	0.3344	0.3312	0.2983	0.3073	0.3184	0.3344	0.3376	0.3750
3/8	24	NF-3	0.3750	0.3684	0.3479	0.3455	0.3239	0.3299	0.3364	0.3479	0.3503	0.3750
7/16	14	NC-3	0.4375	0.4277	0.3911	0.3875	0.3499	0.3602	0.3721	0.3911	0.3947	0.4375
7/16	20	NF-3	0.4375	0.4303	0.4050	0.4024	0.3762	0.3834	0.3906	0.4050	0.4076	0.4375
1/2	13	NC-3	0.5000	0.4896	0.4500	0.4463	0.4056	0.4167	0.4290	0.4500	0.4537	0.5000
1/2	20	NF-3	0.5000	0.4928	0.4675	0.4649	0.4387	0.4459	0.4531	0.4675	0.4701	0.5000
9/16	12	NC-3	0.5625	0.5513	0.5084	0.5044	0.4603	0.4723	0.4850	0.5084	0.5124	0.5625
9/16	18	NF-3	0.5625	0.5543	0.5264	0.5234	0.4943	0.5024	0.5100	0.5264	0.5294	0.5625
5/8	11	NC-3	0.6250	0.6132	0.5660	0.5618	0.5135	0.5266	0.5397	0.5660	0.5702	0.6250
5/8	18	NF-3	0.6250	0.6168	0.5889	0.5859	0.5568	0.5649	0.5725	0.5889	0.5919	0.6250
3/4	10	NC-3	0.7500	0.7372	0.6850	0.6805	0.6273	0.6417	0.6553	0.6850	0.6895	0.7500
3/4	16	NF-3	0.7500	0.7410	0.7094	0.7062	0.6733	0.6823	0.6903	0.7094	0.7126	0.7500
7/8	9	NC-3	0.8750	0.8610	0.8028	0.7979	0.7387	0.7547	0.7689	0.8028	0.8077	0.8750
7/8	14	NF-3	0.8750	0.8652	0.8286	0.8250	0.7874	0.7977	0.8062	0.8286	0.8322	0.8750
1	8	NC-3	1.0000	0.9848	0.9188	0.9134	0.8466	0.8647	0.8795	0.9188	0.9242	1.0000
1	14	NF-3	1.0000	0.9902	0.9536	0.9500	0.9124	0.9227	0.9312	0.9536	0.9572	1.0000
1 1/8	7	NC-3	1.1250	1.1080	1.0322	1.0263	0.9497	0.9704	0.9858	1.0322	1.0381	1.1250
1 1/8	8	N-3	1.1250	1.1098	1.0438	1.0383	0.9716	0.9897	1.0045	1.0438	1.0493	1.1250
1 1/8	12	NF-3	1.1250	1.1138	1.0709	1.0669	1.0228	1.0348	1.0438	1.0709	1.0749	1.1250

[a] See Fig. 1.

TABLE 16b—*Class 3, External and Internal Threads—NC, NF, and 8N Series*

DESIGNATION			LIMITS OF SIZE								
			External threads					Internal threads				
Size	Threads per inch	Thread symbol	Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
			Max	Min	Max	Min		Min	Max	Min	Max	Min
1¼	7	NC-3	1.2500	1.2330	1.1572	1.1513	1.0747	1.0954	1.1108	1.1572	1.1631	1.2500
1¼	8	N-3	1.2500	1.2348	1.1688	1.1630	1.0966	1.1147	1.1295	1.1688	1.1746	1.2500
1¼	12	NF-3	1.2500	1.2388	1.1959	1.1919	1.1478	1.1598	1.1688	1.1959	1.1999	1.2500
1⅜	6	NC-3	1.3750	1.3548	1.2667	1.2596	1.1705	1.1946	1.2126	1.2667	1.2738	1.3750
1⅜	8	N-3	1.3750	1.3598	1.2938	1.2877	1.2216	1.2397	1.2545	1.2938	1.2999	1.3750
1⅜	12	NF-3	1.3750	1.3638	1.3209	1.3169	1.2728	1.2848	1.2938	1.3209	1.3249	1.3750
1½	6	NC-3	1.5000	1.4798	1.3917	1.3846	1.2955	1.3196	1.3376	1.3917	1.3988	1.5000
1½	8	N-3	1.5000	1.4848	1.4188	1.4125	1.3466	1.3647	1.3795	1.4188	1.4251	1.5000
1½	12	NF-3	1.5000	1.4888	1.4459	1.4419	1.3978	1.4098	1.4188	1.4459	1.4499	1.5000
1⅝	8	N-3	1.6250	1.6098	1.5438	1.5373	1.4716	1.4897	1.5045	1.5438	1.5503	1.6250
1¾	5	NC-3	1.7500	1.7268	1.6201	1.6119	1.5046	1.5335	1.5551	1.6201	1.6283	1.7500
1¾	8	N-3	1.7500	1.7348	1.6688	1.6620	1.5966	1.6147	1.6295	1.6688	1.6756	1.7500
1⅞	8	N-3	1.8750	1.8598	1.7938	1.7868	1.7216	1.7397	1.7545	1.7938	1.8008	1.8750
2	4½	NC-3	2.0000	1.9746	1.8557	1.8468	1.7274	1.7594	1.7835	1.8557	1.8646	2.0000
2	8	N-3	2.0000	1.9848	1.9188	1.9115	1.8466	1.8647	1.8795	1.9188	1.9261	2.0000
2⅛	8	N-3	2.1250	2.1098	2.0438	2.0363	1.9716	1.9897	2.0045	2.0438	2.0513	2.1250
2¼	4½	NC-3	2.2500	2.2246	2.1057	2.0968	1.9774	2.0094	2.0335	2.1057	2.1146	2.2500
2¼	8	N-3	2.2500	2.2348	2.1688	2.1611	2.0966	2.1147	2.1295	2.1688	2.1765	2.2500
2½	4	NC-3	2.5000	2.4720	2.3376	2.3279	2.1933	2.2294	2.2564	2.3376	2.3473	2.5000
2½	8	N-3	2.5000	2.4848	2.4188	2.4106	2.3466	2.3647	2.3795	2.4188	2.4270	2.5000
2¾	4	NC-3	2.7500	2.7220	2.5876	2.5779	2.4433	2.4794	2.5064	2.5876	2.5973	2.7500
2¾	8	N-3	2.7500	2.7348	2.6688	2.6601	2.5966	2.6147	2.6295	2.6688	2.6775	2.7500
3	4	NC-3	3.0000	2.9720	2.8376	2.8279	2.6933	2.7294	2.7564	2.8376	2.8473	3.0000
3	8	N-3	3.0000	2.9848	2.9188	2.9096	2.8466	2.8647	2.8795	2.9188	2.9280	3.0000
3¼	4	NC-3	3.2500	3.2220	3.0876	3.0779	2.9433	2.9794	3.0064	3.0876	3.0973	3.2500
3¼	8	N-3	3.2500	3.2348	3.1688	3.1595	3.0966	3.1147	3.1295	3.1688	3.1781	3.2500
3½	4	NC-3	3.5000	3.4720	3.3376	3.3279	3.1933	3.2294	3.2564	3.3376	3.3473	3.5000
3½	8	N-3	3.5000	3.4848	3.4188	3.4095	3.3466	3.3647	3.3795	3.4188	3.4281	3.5000
3¾	4	NC-3	3.7500	3.7220	3.5876	3.5779	3.4433	3.4794	3.5064	3.5876	3.5973	3.7500
3¾	8	N-3	3.7500	3.7348	3.6688	3.6594	3.5966	3.6147	3.6295	3.6688	3.6782	3.7500
4	4	NC-3	4.0000	3.9720	3.8376	3.8279	3.6933	3.7294	3.7564	3.8376	3.8473	3.0000
4	8	N-3	4.0000	3.9848	3.9188	3.9093	3.8466	3.8647	3.8795	3.9188	3.9283	4.0000
4¼	8	N-3	4.2500	4.2348	4.1688	4.1592	4.0966	4.1147	4.1295	4.1688	4.1784	4.2500
4½	8	N-3	4.5000	4.4848	4.4188	4.4091	4.3466	4.3647	4.3795	4.4188	4.4285	4.5000
4¾	8	N-3	4.7500	4.7348	4.6688	4.6590	4.5966	4.6147	4.6295	4.6688	4.6786	4.7500
5	8	N-3	5.0000	4.9848	4.9188	4.9089	4.8466	4.8647	4.8795	4.9188	4.9287	5.0000
5¼	8	N-3	5.2500	5.2348	5.1688	5.1589	5.0966	5.1147	5.1295	5.1688	5.1787	5.2500
5½	8	N-3	5.5000	5.4848	5.4188	5.4088	5.3466	5.3647	5.3795	5.4188	5.4288	5.5000
5¾	8	N-3	5.7500	5.7348	5.6688	5.6587	5.5966	5.6147	5.6295	5.6688	5.6789	5.7500
6	8	N-3	6.0000	5.9848	5.9188	5.9086	5.8466	5.8647	5.8795	5.9188	5.9290	6.0000

[a] See Fig. 1.

Section 5—Special Threads

21. The special thread specifications in this section cover nonstandard or special combinations of diameter, pitch, and length of engagement in which the tolerances are derived from and are a function of the diameter, pitch, and length of engagement. (See formulas in Appendix D).

22. This section includes tabulated thread data (see SAE Tables 17 to 20) for selected combinations of diameter and pitch with length of engagement equal to $9p$, together with the limits of size for the NEF, 12N, and 16N thread series, some of which are designated as Unified Special Threads. Thread data for other combinations of diameter, pitch, and engagement within the fundamental limitations on design imposed by combining the extreme tolerances of pitch diameter, major diameter, and minor diameter are given in SAE Tables 22 to 31 and Appendix D.

23. The third column ($9 \times$ pitch) in the following tables is the length of thread engagement upon which the given pitch-diameter limits are based.

The pitch-diameter limits are applicable to a length of engagement of from 5 to 15 times the pitch. (This should not be confused with the lengths of thread on the mating parts, as they may exceed the length of engagement by a considerable amount.)

Thread gages based on a nominal length of nine threads will, of course, be suited to any lesser length of engagement, and ordinarily to greater lengths of engagement, provided that the lead errors are kept correspondingly low.

Thus, ordinarily but one set of gages will be required for any one size and pitch except to satisfy unusual conditions. In such cases, refer to thread data for other combinations of diameter, pitch, and engagement given in SAE Tables 22 to 31 and Appendix D. The step-table allowances and pitch-diameter tolerances and minor-diameter tolerances for lengths of engagement, as given in SAE Tables 22 to 31, require but two sets of gages to cover all conditions of engagement within the range shown in the tables. For extreme conditions of engagement, the allowance and tolerance should be derived from the formulas in Appendix E or the table notes.

24. **Form of Thread**

The basic thread form is the Unified and American Standard.

25. For formulas for limits of size, see Appendix D.

26. **Internal-Thread Minor-Diameter Tolerances**

Tolerances for all diameters, lengths of engagement, and the selected pitches recommended in this section are given in SAE Table 31 for Classes 1B, 2B, and 3B and in SAE Table 32 for Classes 2 and 3.

The principal practical factors which govern these tolerances are tapping difficulties, particularly tap breakage in the small sizes, and depth of engagement. Depth of engagement correlates with the stripping strength of the thread assembly and thus also with the length of engagement. It also correlates with the tendency toward disengagement of the threads on one side, when assembly is eccentric. The amount of possible eccentricity is one half of the sum of the pitch-diameter allowance and tolerances on both mating parts. For a given pitch, or height of thread, this sum increases with the diameter; and accordingly, this factor would require a decrease in minor-diameter tolerance with increase in diameter.

27. **Unified Tolerances, Classes 1B, 2B, and 3B**

The Unified tolerances given in SAE Table 31, namely those for lengths of engagement from $\frac{3}{8}D$ to $1\frac{1}{2}D$, are based on the following empirical formula, which meets the above conditions:

$$\text{Tolerance} = 0.05\sqrt[3]{p^2} + 0.03\ p/D - 0.002$$

The fundamental basis of this formula and of SAE Table 31 is the set of minor-diameter tolerances which have been established for many years for the coarse- and fine-thread series on the basis of experience in production and use. That is, values in the table corresponding to standard diameters, pitches, and lengths of engagement from $\frac{3}{8}D$ to $1\frac{1}{2}D$ are in close agreement with the previously used NC and NF values.

There are, however, certain limitations applied in connection with the above formula at and near the extremes of the diameter ranges for a given pitch. For the smallest sizes at the left of the table, the tolerances are not greater than $0.394p$, which corresponds to a thread height of 53% of the basic thread height. For pitches of 12 threads per inch or coarser, at the right of the table, the tolerances are not less than $0.120p$, which corresponds to a thread height of 74%. Also for pitches finer than 12 threads per inch, the tolerances are not less than $0.23p - 1.5p^2$, which corresponds to a thread height of 67% for 80 threads per inch graduating to 74% for 14 threads per inch. (It thus develops that the tolerance for all UNC, UNF, 8N, and 12N sizes 1 in. in diameter and larger is $0.120p$.)

In addition to the Unified values, tolerances are given for lengths of engagement less than $\frac{1}{3}D$. These are $\frac{1}{2}$ of the formula values. Also tolerances are given for lengths of engagement from $\frac{1}{8}D$ to $\frac{3}{8}D$ which are $\frac{3}{4}$ of the Unified tolerances and for lengths of engagement over $1\frac{1}{2}D$ which are $1\frac{1}{4}$ times these.

SAE Table 31 thus provides a specific internal minor-diameter tolerance for any given choice of diameter, pitch, and length of engagement, which is expected to fulfill all requirements of good design. The minor-diameter tolerances for all standard series in Classes 1B, 2B, and 3B are in agreement with this table for the lengths of engagement from $\frac{3}{8}D$ to $1\frac{1}{2}D$.

28. **Tolerances for Classes 2 and 3**

The fundamental basis of SAE Table 32 is the present set of minor-diameter tolerances established for the American coarse- and fine-thread series on the basis of experience in production. That is, values in the table corresponding to standard diameters and pitches and lengths of engagement from $\frac{3}{8}D$ to $1\frac{1}{2}D$ are in close agreement with the Classes 2 and 3 NC and NF values, with slight deviations in some cases to conform with formulas used. These formulas subdivide the tolerance-diameter relationship into four zones, with a particular proportion of tolerance to diameter applicable in each zone, and apply to lengths of engagement from $\frac{3}{8}D$ to $1\frac{1}{2}D$. Tolerances for lengths of engagement less than $\frac{1}{3}D$ are $\frac{1}{2}$ of these, for $\frac{1}{3}D$ to $\frac{3}{8}D$ are $\frac{3}{4}$ of these, and for over $1\frac{1}{2}D$ are $1\frac{1}{4}$ times these. However, where the resulting tolerance would make the height of thread less than 53% of the basic thread height, the values are adjusted to produce the 53% height of thread. In the fourth zone, corresponding to the larger diameters at the right of the table, tolerances for lengths of engagement from $\frac{3}{8}D$ to $1\frac{1}{2}D$ are adjusted to equality with Class 2 pitch-diameter tolerances and for lengths greater than $1\frac{1}{2}D$ to equality with Class 1 pitch-diameter tolerances.

TABLE 17a—*Class 2A, Selected Combinations of Special Diameter and Pitch—UN, N, NEF, and NS*

DESIGNATION				EXTERNAL-THREAD LIMITS OF SIZE[a]							
					Major diameter			Pitch diameter[b]			
Size	Threads per inch	Thread symbol	L_e, 9 × PITCH	Allowance	Limits		Tolerance	Limits		Tolerance	Minor diameter[c]
					Max[d]	Min		Max[d]	Min		
10 (0.190)	28	NS-2A	0.3214	0.0010	0.1890	0.1825	0.0065	0.1658	0.1625	0.0033	0.1452
10 (0.190)	36	NS-2A	0.2500	0.0009	0.1891	0.1836	0.0055	0.1711	0.1681	0.0030	0.1550
10 (0.190)	40	NS-2A	0.2250	0.0009	0.1891	0.1840	0.0051	0.1729	0.1700	0.0029	0.1584
10 (0.190)	48	NS-2A	0.1875	0.0008	0.1892	0.1847	0.0045	0.1757	0.1731	0.0026	0.1636
10 (0.190)	56	NS-2A	0.1607	0.0007	0.1893	0.1852	0.0041	0.1777	0.1752	0.0025	0.1674
12 (0.216)	32	NEF-2A	0.2812	0.0009	0.2151	0.2091	0.0060	0.1948	0.1917	0.0031	0.1768
12 (0.216)	36	NS-2A	0.2500	0.0009	0.2151	0.2096	0.0055	0.1971	0.1941	0.0030	0.1810
12 (0.216)	40	NS-2A	0.2250	0.0009	0.2151	0.2100	0.0051	0.1989	0.1960	0.0029	0.1844
12 (0.216)	48	NS-2A	0.1875	0.0008	0.2152	0.2107	0.0045	0.2017	0.1991	0.0026	0.1896
12 (0.216)	56	NS-2A	0.1607	0.0007	0.2153	0.2112	0.0041	0.2037	0.2012	0.0025	0.1934
1/4	24	NS-2A	0.3750	0.0011	0.2489	0.2417	0.0072	0.2218	0.2181	0.0037	0.1978
1/4	32	NEF-2A	0.2812	0.0010	0.2490	0.2430	0.0060	0.2287	0.2255	0.0032	0.2107
1/4	36	UN-2A	0.2500	0.0009	0.2491	0.2436	0.0055	0.2311	0.2280	0.0031	0.2150
1/4	40	NS-2A	0.2250	0.0009	0.2491	0.2440	0.0051	0.2329	0.2300	0.0029	0.2184
1/4	48	NS-2A	0.1875	0.0008	0.2492	0.2447	0.0045	0.2357	0.2330	0.0027	0.2236
1/4	56	NS-2A	0.1607	0.0008	0.2492	0.2451	0.0041	0.2376	0.2350	0.0026	0.2273
5/16	20	NS-2A	0.4500	0.0012	0.3113	0.3032	0.0081	0.2788	0.2748	0.0040	0.2500
5/16	28	NS-2A	0.3214	0.0010	0.3115	0.3050	0.0065	0.2883	0.2849	0.0034	0.2677
5/16	32	NEF-2A	0.2812	0.0010	0.3115	0.3055	0.0060	0.2912	0.2880	0.0032	0.2732
5/16	36	UN-2A	0.2500	0.0009	0.3116	0.3061	0.0055	0.2936	0.2905	0.0031	0.2775
5/16	40	NS-2A	0.2250	0.0009	0.3116	0.3065	0.0051	0.2954	0.2925	0.0029	0.2809
5/16	48	NS-2A	0.1875	0.0008	0.3117	0.3072	0.0045	0.2982	0.2955	0.0027	0.2861
3/8	18	NS-2A	0.5000	0.0013	0.3737	0.3650	0.0087	0.3376	0.3333	0.0043	0.3055
3/8	20	NS-2A	0.4500	0.0012	0.3738	0.3657	0.0081	0.3413	0.3372	0.0041	0.3125
3/8	28	NS-2A	0.3214	0.0011	0.3739	0.3674	0.0065	0.3507	0.3471	0.0036	0.3301
3/8	32	NEF-2A	0.2812	0.0010	0.3740	0.3680	0.0060	0.3537	0.3503	0.0034	0.3357
3/8	36	UN-2A	0.2500	0.0010	0.3740	0.3685	0.0055	0.3560	0.3528	0.0032	0.3399
3/8	40	NS-2A	0.2250	0.0009	0.3741	0.3690	0.0051	0.3579	0.3548	0.0031	0.3434
7/16	16	NS-2A	0.5625	0.0014	0.4361	0.4267	0.0094	0.3955	0.3909	0.0046	0.3594
7/16	18	NS-2A	0.5000	0.0013	0.4362	0.4275	0.0087	0.4001	0.3958	0.0043	0.3680
7/16	24	NS-2A	0.3750	0.0011	0.4364	0.4292	0.0072	0.4093	0.4055	0.0038	0.3853
7/16	28	UNEF-2A	0.3214	0.0011	0.4364	0.4299	0.0065	0.4132	0.4096	0.0036	0.3926
7/16	32	NS-2A	0.2812	0.0010	0.4365	0.4305	0.0060	0.4162	0.4128	0.0034	0.3982
1/2	14	NS-2A	0.6429	0.0015	0.4985	0.4882	0.0103	0.4521	0.4471	0.0050	0.4109
1/2	16	NS-2A	0.5625	0.0014	0.4986	0.4892	0.0094	0.4580	0.4533	0.0047	0.4219
1/2	18	NS-2A	0.5000	0.0013	0.4987	0.4900	0.0087	0.4626	0.4582	0.0044	0.4305
1/2	24	NS-2A	0.3750	0.0012	0.4988	0.4916	0.0072	0.4717	0.4678	0.0039	0.4477
1/2	28	UNEF-2A	0.3214	0.0011	0.4989	0.4924	0.0065	0.4757	0.4720	0.0037	0.4551
1/2	32	NS-2A	0.2812	0.0010	0.4990	0.4930	0.0060	0.4787	0.4752	0.0035	0.4607
9/16	14	NS-2A	0.6429	0.0015	0.5610	0.5507	0.0103	0.5146	0.5096	0.0050	0.4734
9/16	16	NS-2A	0.5625	0.0014	0.5611	0.5517	0.0094	0.5205	0.5158	0.0047	0.4844
9/16	20	NS-2A	0.4500	0.0013	0.5612	0.5531	0.0081	0.5287	0.5245	0.0042	0.4999
9/16	24	NEF-2A	0.3750	0.0012	0.5613	0.5541	0.0072	0.5342	0.5303	0.0039	0.5102
9/16	28	UN-2A	0.3214	0.0011	0.5614	0.5549	0.0065	0.5382	0.5345	0.0037	0.5176
9/16	32	NS-2A	0.2812	0.0010	0.5615	0.5555	0.0060	0.5412	0.5377	0.0035	0.5232
5/8	12	N-2A	0.7500	0.0016	0.6234	0.6120	0.0114	0.5693	0.5639	0.0054	0.5212
5/8	14	NS-2A	0.6429	0.0015	0.6235	0.6132	0.0103	0.5771	0.5720	0.0051	0.5359
5/8	16	NS-2A	0.5625	0.0014	0.6236	0.6142	0.0094	0.5830	0.5782	0.0048	0.5469
5/8	20	NS-2A	0.4500	0.0013	0.6237	0.6156	0.0081	0.5912	0.5869	0.0043	0.5624
5/8	24	NEF-2A	0.3750	0.0012	0.6238	0.6166	0.0072	0.5967	0.5927	0.0040	0.5727
5/8	28	UN-2A	0.3214	0.0011	0.6239	0.6174	0.0065	0.6007	0.5969	0.0038	0.5801
5/8	32	NS-2A	0.2812	0.0011	0.6239	0.6179	0.0060	0.6036	0.6000	0.0036	0.5856
11/16	12	N-2A	0.7500	0.0016	0.6859	0.6745	0.0114	0.6318	0.6264	0.0054	0.5837
11/16	24	NEF-2A	0.3750	0.0012	0.6863	0.6791	0.0072	0.6592	0.6552	0.0040	0.6352

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.
[c] See Fig. 1.
[d] Maximum limits are increased by the amount of the allowance for threads which are electroplated or have coatings of similar thicknesses. Where the allowance is not sufficient for the required thickness of plating or coating, special provisions are necessary.

TABLE 17b—*Class 2A, Selected Combinations of Special Diameter and Pitch—UN, N, UNEF, NEF, and NS*

DESIGNATION				EXTERNAL-THREAD LIMITS OF SIZE[a]							
					Major diameter			Pitch diameter[b]			
					Limits			Limits			
Size	Threads per inch	Thread symbol	*Le*, 9 × PITCH	Allowance	Max[d]	Min	Tolerance	Max[d]	Min	Tolerance	Minor diameter[c]
3/4	12	N-2A	0.7500	0.0017	0.7483	0.7369	0.0114	0.6942	0.6887	0.0055	0.6461
3/4	14	NS-2A	0.6429	0.0015	0.7485	0.7382	0.0103	0.7021	0.6970	0.0051	0.6609
3/4	18	NS-2A	0.5000	0.0014	0.7486	0.7399	0.0087	0.7125	0.7079	0.0046	0.6804
3/4	20	UNEF-2A	0.4500	0.0013	0.7487	0.7406	0.0081	0.7162	0.7118	0.0044	0.6874
3/4	24	NS-2A	0.3750	0.0012	0.7488	0.7416	0.0072	0.7217	0.7176	0.0041	0.6977
3/4	28	UN-2A	0.3214	0.0012	0.7488	0.7423	0.0065	0.7256	0.7218	0.0038	0.7050
3/4	32	NS-2A	0.2812	0.0011	0.7489	0.7429	0.0060	0.7286	0.7250	0.0036	0.7106
13/16	12	N-2A	0.7500	0.0017	0.8108	0.7994	0.0114	0.7567	0.7512	0.0055	0.7086
13/16	16	UN-2A	0.5625	0.0015	0.8110	0.8016	0.0094	0.7704	0.7655	0.0049	0.7343
13/16	20	UNEF-2A	0.4500	0.0013	0.8112	0.8031	0.0081	0.7787	0.7743	0.0044	0.7498
7/8	10	NS-2A	0.9000	0.0018	0.8732	0.8603	0.0129	0.8082	0.8022	0.0060	0.7505
7/8	12	N-2A	0.7500	0.0017	0.8733	0.8619	0.0114	0.8192	0.8137	0.0055	0.7711
7/8	16	UN-2A	0.5625	0.0015	0.8735	0.8641	0.0094	0.8329	0.8280	0.0049	0.7968
7/8	18	NS-2A	0.5000	0.0014	0.8736	0.8649	0.0087	0.8375	0.8329	0.0046	0.8054
7/8	20	UNEF-2A	0.4500	0.0013	0.8737	0.8656	0.0081	0.8412	0.8368	0.0044	0.8124
7/8	24	NS-2A	0.3750	0.0012	0.8738	0.8666	0.0072	0.8467	0.8426	0.0041	0.8227
7/8	28	UN-2A	0.3214	0.0012	0.8738	0.8673	0.0065	0.8506	0.8468	0.0038	0.8300
7/8	32	NS-2A	0.2812	0.0011	0.8739	0.8679	0.0060	0.8536	0.8500	0.0036	0.8356
15/16	12	UN-2A	0.7500	0.0017	0.9358	0.9244	0.0114	0.8817	0.8760	0.0057	0.8336
15/16	16	UN-2A	0.5625	0.0015	0.9360	0.9266	0.0094	0.8954	0.8904	0.0050	0.8593
15/16	20	UNEF-2A	0.4500	0.0014	0.9361	0.9280	0.0081	0.9036	0.8991	0.0045	0.8748
1	10	NS-2A	0.9000	0.0018	0.9982	0.9853	0.0129	0.9332	0.9270	0.0062	0.8755
1	16	UN-2A	0.5625	0.0015	0.9985	0.9891	0.0094	0.9579	0.9529	0.0050	0.9218
1	18	NS-2A	0.5000	0.0014	0.9986	0.9899	0.0087	0.9625	0.9578	0.0047	0.9304
1	20	UNEF-2A	0.4500	0.0014	0.9986	0.9905	0.0081	0.9661	0.9616	0.0045	0.9373
1	24	NS-2A	0.3750	0.0013	0.9987	0.9915	0.0072	0.9716	0.9674	0.0042	0.9476
1	28	UN-2A	0.3214	0.0012	0.9988	0.9923	0.0065	0.9756	0.9716	0.0040	0.9550
1	32	NS-2A	0.2812	0.0011	0.9989	0.9929	0.0060	0.9786	0.9748	0.0038	0.9606
1 1/16	12	UN-2A	0.7500	0.0017	1.0608	1.0494	0.0114	1.0067	1.0010	0.0057	0.9586
1 1/16	16	UN-2A	0.5625	0.0015	1.0610	1.0516	0.0094	1.0204	1.0154	0.0050	0.9843
1 1/16	18	NEF-2A	0.5000	0.0014	1.0611	1.0524	0.0087	1.0250	1.0203	0.0047	0.9929
1 1/8	10	NS-2A	0.9000	0.0018	1.1232	1.1103	0.0129	1.0582	1.0520	0.0062	1.0005
1 1/8	14	NS-2A	0.6429	0.0016	1.1234	1.1131	0.0103	1.0770	1.0717	0.0053	1.0358
1 1/8	16	UN-2A	0.5625	0.0015	1.1235	1.1141	0.0094	1.0829	1.0779	0.0050	1.0468
1 1/8	18	NEF-2A	0.5000	0.0014	1.1236	1.1149	0.0087	1.0875	1.0828	0.0047	1.0554
1 1/8	20	UN-2A	0.4500	0.0014	1.1236	1.1155	0.0081	1.0911	1.0866	0.0045	1.0623
1 1/8	24	NS-2A	0.3750	0.0013	1.1237	1.1165	0.0072	1.0966	1.0924	0.0042	1.0726
1 1/8	28	UN-2A	0.3214	0.0012	1.1238	1.1173	0.0065	1.1006	1.0966	0.0040	1.0800
1 3/16	12	UN-2A	0.7500	0.0017	1.1858	1.1744	0.0114	1.1317	1.1259	0.0058	1.0836
1 3/16	16	UN-2A	0.5625	0.0015	1.1860	1.1766	0.0094	1.1454	1.1403	0.0051	1.1093
1 3/16	18	NEF-2A	0.5000	0.0015	1.1860	1.1773	0.0087	1.1499	1.1450	0.0049	1.1178
1 1/4	10	NS-2A	0.9000	0.0019	1.2481	1.2352	0.0129	1.1831	1.1768	0.0063	1.1254
1 1/4	14	NS-2A	0.6429	0.0016	1.2484	1.2381	0.0103	1.2020	1.1966	0.0054	1.1608
1 1/4	16	UN-2A	0.5625	0.0015	1.2485	1.2391	0.0094	1.2079	1.2028	0.0051	1.1718
1 1/4	18	NEF-2A	0.5000	0.0015	1.2485	1.2398	0.0087	1.2124	1.2075	0.0049	1.1803
1 1/4	20	UN-2A	0.4500	0.0014	1.2486	1.2405	0.0081	1.2161	1.2114	0.0047	1.1873
1 1/4	24	NS-2A	0.3750	0.0013	1.2487	1.2415	0.0072	1.2216	1.2173	0.0043	1.1976
1 5/16	12	UN-2A	0.7500	0.0017	1.3108	1.2994	0.0114	1.2567	1.2509	0.0058	1.2086
1 5/16	16	UN-2A	0.5625	0.0015	1.3110	1.3016	0.0094	1.2704	1.2653	0.0051	1.2343
1 5/16	18	NEF-2A	0.5000	0.0015	1.3110	1.3023	0.0087	1.2749	1.2700	0.0049	1.2428

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.
[c] See Fig. 1.
[d] Maximum limits are increased by the amount of the allowance for threads which are electroplated or have coatings of similar thicknesses. Where the allowance is not sufficient for the required thickness of plating or coating, special provisions are necessary.

TABLE 17c—*Class 2A, Selected Combinations of Special Diameter and Pitch—UN, N, UNEF, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE[a]							
					Major diameter			Pitch diameter[b]			
					Limits		Tolerance	Limits		Tolerance	Minor diameter[c]
Size	Threads per inch	Thread symbol		Allowance	Max[d]	Min		Max[d]	Min		
1⅜	10	NS-2A	0.9000	0.0019	1.3731	1.3602	0.0129	1.3081	1.3018	0.0063	1.2504
1⅜	14	NS-2A	0.6429	0.0016	1.3734	1.3631	0.0103	1.3270	1.3216	0.0054	1.2858
1⅜	16	UN-2A	0.5625	0.0015	1.3735	1.3641	0.0094	1.3329	1.3278	0.0051	1.2968
1⅜	18	NEF-2A	0.5000	0.0015	1.3735	1.3648	0.0087	1.3374	1.3325	0.0049	1.3053
1⁷⁄₁₆	12	UN-2A	0.7500	0.0018	1.4357	1.4243	0.0114	1.3816	1.3757	0.0059	1.3335
1⁷⁄₁₆	16	UN-2A	0.5625	0.0016	1.4359	1.4265	0.0094	1.3953	1.3901	0.0052	1.3592
1⁷⁄₁₆	18	NEF-2A	0.5000	0.0015	1.4360	1.4273	0.0087	1.3999	1.3949	0.0050	1.3678
1½	10	NS-2A	0.9000	0.0019	1.4981	1.4852	0.0129	1.4331	1.4267	0.0064	1.3754
1½	14	NS-2A	0.6429	0.0017	1.4983	1.4880	0.0103	1.4519	1.4464	0.0055	1.4107
1½	16	UN-2A	0.5625	0.0016	1.4984	1.4890	0.0094	1.4578	1.4526	0.0052	1.4217
1½	18	NEF-2A	0.5000	0.0015	1.4985	1.4898	0.0087	1.4624	1.4574	0.0050	1.4303
1½	20	UN-2A	0.4500	0.0014	1.4986	1.4905	0.0081	1.4661	1.4613	0.0048	1.4373
1½	24	NS-2A	0.3750	0.0013	1.4987	1.4915	0.0072	1.4716	1.4672	0.0044	1.4476
1⁹⁄₁₆	16	N-2A	0.5625	0.0016	1.5609	1.5515	0.0094	1.5203	1.5151	0.0052	1.4842
1⁹⁄₁₆	18	NEF-2A	0.5000	0.0015	1.5610	1.5523	0.0087	1.5249	1.5199	0.0050	1.4928
1⅝	6	NS-2A	1.5000	0.0024	1.6226	1.6044	0.0182	1.5143	1.5062	0.0081	1.4181
1⅝	7	NS-2A	1.2857	0.0023	1.6227	1.6063	0.0164	1.5299	1.5224	0.0075	1.4474
1⅝	10	NS-2A	0.9000	0.0019	1.6231	1.6102	0.0129	1.5581	1.5517	0.0064	1.5004
1⅝	12	N-2A	0.7500	0.0018	1.6232	1.6118	0.0114	1.5691	1.5632	0.0059	1.5210
1⅝	14	NS-2A	0.6429	0.0017	1.6233	1.6130	0.0103	1.5769	1.5714	0.0055	1.5357
1⅝	16	N-2A	0.5625	0.0016	1.6234	1.6140	0.0094	1.5828	1.5776	0.0052	1.5467
1⅝	18	NEF-2A	0.5000	0.0015	1.6235	1.6148	0.0087	1.5874	1.5824	0.0050	1.5553
1⅝	20	NS-2A	0.4500	0.0014	1.6236	1.6155	0.0081	1.5911	1.5863	0.0048	1.5623
1⅝	24	NS-2A	0.3750	0.0013	1.6237	1.6165	0.0072	1.5966	1.5922	0.0044	1.5726
1¹¹⁄₁₆	16	N-2A	0.5625	0.0016	1.6859	1.6765	0.0094	1.6453	1.6400	0.0053	1.6092
1¹¹⁄₁₆	18	NEF-2A	0.5000	0.0015	1.6860	1.6773	0.0087	1.6499	1.6448	0.0051	1.6178
1¾	6	NS-2A	1.5000	0.0025	1.7475	1.7293	0.0182	1.6392	1.6310	0.0082	1.5430
1¾	7	NS-2A	1.2857	0.0023	1.7477	1.7313	0.0164	1.6549	1.6473	0.0076	1.5724
1¾	8	UN-2A	1.1250	0.0021	1.7479	1.7329	0.0150	1.6667	1.6596	0.0071	1.5945
1¾	10	NS-2A	0.9000	0.0019	1.7481	1.7352	0.0129	1.6831	1.6766	0.0065	1.6254
1¾	12	UN-2A	0.7500	0.0018	1.7482	1.7368	0.0114	1.6941	1.6881	0.0060	1.6460
1¾	14	NS-2A	0.6429	0.0017	1.7483	1.7380	0.0103	1.7019	1.6963	0.0056	1.6607
1¾	16	UNEF-2A	0.5625	0.0016	1.7484	1.7390	0.0094	1.7078	1.7025	0.0053	1.6717
1¾	18	NS-2A	0.5000	0.0015	1.7485	1.7398	0.0087	1.7124	1.7073	0.0051	1.6803
1¾	20	UN-2A	0.4500	0.0015	1.7485	1.7404	0.0081	1.7160	1.7112	0.0048	1.6872
1¹³⁄₁₆	16	N-2A	0.5625	0.0016	1.8109	1.8015	0.0094	1.7703	1.7650	0.0053	1.7342
1⅞	6	NS-2A	1.5000	0.0025	1.8725	1.8543	0.0182	1.7642	1.7560	0.0082	1.6680
1⅞	7	NS-2A	1.2857	0.0023	1.8727	1.8563	0.0164	1.7799	1.7723	0.0076	1.6974
1⅞[e]	8	NS-2A	1.1250	0.0021	1.8729	1.8579	0.0150	1.7917	1.7846	0.0071	1.7195
1⅞	10	NS-2A	0.9000	0.0019	1.8731	1.8602	0.0129	1.8081	1.8016	0.0065	1.7504
1⅞	12	N-2A	0.7500	0.0018	1.8732	1.8618	0.0114	1.8191	1.8131	0.0060	1.7710
1⅞	14	NS-2A	0.6429	0.0017	1.8733	1.8630	0.0103	1.8269	1.8213	0.0056	1.7857
1⅞	16	N-2A	0.5625	0.0016	1.8734	1.8640	0.0094	1.8328	1.8275	0.0053	1.7967
1⅞	18	NS-2A	0.5000	0.0015	1.8735	1.8648	0.0087	1.8374	1.8323	0.0051	1.8053
1⅞	20	NS-2A	0.4500	0.0015	1.8735	1.8654	0.0081	1.8410	1.8362	0.0048	1.8122
1¹⁵⁄₁₆	16	N-2A	0.5625	0.0016	1.9359	1.9265	0.0094	1.8953	1.8899	0.0054	1.8592

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.
[c] See Fig. 1.
[d] Maximum limits are increased by the amount of the allowance for threads which are electroplated or have coatings of similar thicknesses. Where the allowance is not sufficient for the required thickness of plating or coating, special provisions are necessary.
[e] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 17d—*Class 2A, Selected Combinations of Special Diameter and Pitch—UN, N, UNEF, NEF, and NS*

DESIGNATION				EXTERNAL-THREAD LIMITS OF SIZE[a]							
					Major diameter			Pitch diameter[b]			
Size	Threads per inch	Thread symbol	L_e, 9 × PITCH	Allowance	Limits		Tolerance	Limits		Tolerance	Minor diameter[c]
					Max[d]	Min		Max[d]	Min		
2	6	NS-2A	1.5000	0.0025	1.9975	1.9793	0.0182	1.8892	1.8809	0.0083	1.7930
2	7	NS-2A	1.2857	0.0023	1.9977	1.9813	0.0164	1.9049	1.8972	0.0077	1.8224
2	8	UN-2A	1.1250	0.0022	1.9978	1.9828	0.0150	1.9166	1.9094	0.0072	1.8444
2	10	NS-2A	0.9000	0.0020	1.9980	1.9851	0.0129	1.9330	1.9265	0.0065	1.8753
2	12	UN-2A	0.7500	0.0018	1.9982	1.9868	0.0114	1.9441	1.9380	0.0061	1.8960
2	14	NS-2A	0.6429	0.0017	1.9983	1.9880	0.0103	1.9519	1.9462	0.0057	1.9107
2	16	UNEF-2A	0.5625	0.0016	1.9984	1.9890	0.0094	1.9578	1.9524	0.0054	1.9217
2	18	NS-2A	0.5000	0. 015	1.9985	1.9898	0.0087	1.9624	1.9573	0.0051	1.9303
2	20	UN-2A	0.4500	0.0015	1.9985	1.9904	0.0081	1.9660	1.9611	0.0049	1.9372
2 1/16	16	N-2A	0.5625	0.0016	2.0609	2.0515	0.0094	2.0203	2.0149	0.0054	1.9842
2 1/8	12	N-2A	0.7500	0.0018	2.1232	2.1118	0.0114	2.0691	2.0630	0.0061	2.0210
2 1/8	16	N-2A	0.5625	0.0016	2.1234	2.1140	0.0094	2.0828	2.0774	0.0054	2.0467
2 3/16	16	N-2A	0.5625	0.0016	2.1859	2.1765	0.0094	2.1453	2.1399	0.0054	2.1092
2 1/4	6	NS-2A	1.5000	0.0025	2.2475	2.2293	0.0182	2.1392	2.1309	0.0083	2.0430
2 1/4	7	NS-2A	1.2857	0.0024	2.2476	2.2312	0.0164	2.1548	2.1471	0.0077	2.0723
2 1/4	8	UN-2A	1.1250	0.0022	2.2478	2.2328	0.0150	2.1666	2.1594	0.0072	2.0944
2 1/4	10	NS-2A	0.9000	0.0020	2.2480	2.2351	0.0129	2.1830	2.1765	0.0065	2.1253
2 1/4	12	UN-2A	0.7500	0.0018	2.2482	2.2368	0.0114	2.1941	2.1880	0.0061	2.1460
2 1/4	14	NS-2A	0.6429	0.0017	2.2483	2.2380	0.0103	2.2019	2.1962	0.0057	2.1607
2 1/4	16	UN-2A	0.5625	0.0016	2.2484	2.2390	0.0094	2.2078	2.2024	0.0054	2.1717
2 1/4	18	NS-2A	0.5000	0.0015	2.2485	2.2398	0.0087	2.2124	2.2073	0.0051	2.1803
2 1/4	20	UN-2A	0.4500	0.0015	2.2485	2.2404	0.0081	2.2160	2.2111	0.0049	2.1872
2 5/16	16	N-2A	0.5625	0.0017	2.3108	2.3014	0.0094	2.2702	2.2647	0.0055	2.2341
2 3/8	12	N-2A	0.7500	0.0019	2.3731	2.3617	0.0114	2.3190	2.3128	0.0062	2.2709
2 3/8	16	N-2A	0.5625	0.0017	2.3733	2.3639	0.0094	2.3327	2.3272	0.0055	2.2966
2 7/16	16	N-2A	0.5625	0.0017	2.4358	2.4264	0.0094	2.3952	2.3897	0.0055	2.3591
2 1/2	6	NS-2A	1.5000	0.0025	2.4975	2.4793	0.0182	2.3892	2.3808	0.0084	2.2930
2 1/2	7	NS-2A	1.2857	0.0024	2.4976	2.4812	0.0164	2.4048	2.3970	0.0078	2.3223
2 1/2	8	UN-2A	1.1250	0.0022	2.4978	2.4828	0.0150	2.4166	2.4092	0.0074	2.3444
2 1/2	10	NS-2A	0.9000	0.0020	2.4980	2.4851	0.0129	2.4330	2.4263	0.0067	2.3753
2 1/2	12	UN-2A	0.7500	0.0019	2.4981	2.4867	0.0114	2.4440	2.4378	0.0062	2.3959
2 1/2	14	NS-2A	0.6429	0.0017	2.4983	2.4880	0.0103	2.4519	2.4461	0.0058	2.4107
2 1/2	16	UN-2A	0.5625	0.0017	2.4983	2.4889	0.0094	2.4577	2.4522	0.0055	2.4216
2 1/2	18	NS-2A	0.5000	0.0016	2.4984	2.4897	0.0087	2.4623	2.4570	0.0053	2.4302
2 1/2	20	UN-2A	0.4500	0.0015	2.4985	2.4904	0.0081	2.4660	2.4609	0.0051	2.4372
2 5/8	12	N-2A	0.7500	0.0019	2.6231	2.6117	0.0114	2.5690	2.5628	0.0062	2.5209
2 5/8	16	N-2A	0.5625	0.0017	2.6233	2.6139	0.0094	2.5827	2.5772	0.0055	2.5466
2 3/4	6	NS-2A	1.5000	0.0025	2.7475	2.7293	0.0182	2.6392	2.6308	0.0084	2.5430
2 3/4	7	NS-2A	1.2857	0.0024	2.7476	2.7312	0.0164	2.6548	2.6470	0.0078	2.5723
2 3/4	8	UN-2A	1.1250	0.0022	2.7478	2.7328	0.0150	2.6666	2.6592	0.0074	2.5944
2 3/4	10	NS-2A	0.9000	0.0020	2.7480	2.7351	0.0129	2.6830	2.6763	0.0067	2.6253
2 3/4	12	UN-2A	0.7500	0.0019	2.7481	2.7367	0.0114	2.6940	2.6878	0.0062	2.6459
2 3/4	14	NS-2A	0.6429	0.0017	2.7483	2.7380	0.0103	2.7019	2.6961	0.0058	2.6607
2 3/4	16	UN-2A	0.5625	0.0017	2.7483	2.7389	0.0094	2.7077	2.7022	0.0055	2.6716
2 3/4	18	NS-2A	0.5000	0.0016	2.7484	2.7397	0.0087	2.7123	2.7070	0.0053	2.6802
2 7/8	12	N-2A	0.7500	0.0019	2.8731	2.8617	0.0114	2.8190	2.8127	0.0063	2.7709
2 7/8	16	N-2A	0.5625	0.0017	2.8733	2.8639	0.0094	2.8327	2.8271	0.0056	2.7966

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.
[c] See Fig. 1.
[d] Maximum limits are increased by the amount of the allowance for threads which are electroplated or have coatings of similar thicknesses. Where the allowance is not sufficient for the required thickness of plating or coating special provisions are necessary.

TABLE 17e—*Class 2A, Selected Combinations of Special Diameter and Pitch—UN, N, NEF, and NS*

DESIGNATION				EXTERNAL-THREAD LIMITS OF SIZE[a]							
					Major diameter			Pitch diameter[b]			
Size	Threads per inch	Thread symbol	L_e, 9 × PITCH	Allowance	Limits		Tolerance	Limits		Tolerance	Minor diameter[c]
					Max[d]	Min		Max[d]	Min		
3	6	NS-2A	1.5000	0.0026	2.9974	2.9792	0.0182	2.8891	2.8806	0.0085	2.7929
3	7	NS-2A	1.2857	0.0024	2.9976	2.9812	0.0164	2.9048	2.8968	0.0080	2.8223
3	8	UN-2A	1.1250	0.0023	2.9977	2.9827	0.0150	2.9165	2.9090	0.0075	2.8443
3	10	NS-2A	0.9000	0.0020	2.9980	2.9851	0.0129	2.9330	2.9262	0.0068	2.8753
3	12	UN-2A	0.7500	0.0019	2.9981	2.9867	0.0114	2.9440	2.9377	0.0063	2.8959
3	14	NS-2A	0.6429	0.0018	2.9982	2.9879	0.0103	2.9518	2.9459	0.0059	2.9106
3	16	UN-2A	0.5625	0.0017	2.9983	2.9889	0.0094	2.9577	2.9521	0.0056	2.9216
3	18	NS-2A	0.5000	0.0016	2.9984	2.9897	0.0087	2.9623	2.9569	0.0054	2.9302
3 1/8	12	N-2A	0.7500	0.0019	3.1231	3.1117	0.0114	3.0690	3.0627	0.0063	3.0209
3 1/8	16	N-2A	0.5625	0.0017	3.1233	3.1139	0.0094	3.0827	3.0771	0.0056	3.0466
3 1/4	6	NS-2A	1.5000	0.0026	3.2474	3.2292	0.0182	3.1391	3.1306	0.0085	3.0429
3 1/4	7	NS-2A	1.2857	0.0024	3.2476	3.2312	0.0164	3.1548	3.1468	0.0080	3.0723
3 1/4	8	UN-2A	1.1250	0.0023	3.2477	3.2327	0.0150	3.1665	3.1590	0.0075	3.0943
3 1/4	10	NS-2A	0.9000	0.0020	3.2480	3.2351	0.0129	3.1830	3.1762	0.0068	3.1253
3 1/4	12	UN-2A	0.7500	0.0019	3.2481	3.2367	0.0114	3.1940	3.1877	0.0063	3.1459
3 1/4	14	NS-2A	0.6429	0.0018	3.2482	3.2379	0.0103	3.2018	3.1959	0.0059	3.1606
3 1/4	16	UN-2A	0.5625	0.0017	3.2483	3.2389	0.0094	3.2077	3.2021	0.0056	3.1716
3 1/4	18	NS-2A	0.5000	0.0016	3.2484	3.2397	0.0087	3.2123	3.2069	0.0054	3.1802
3 3/8	12	N-2A	0.7500	0.0019	3.3731	3.3617	0.0114	3.3190	3.3126	0.0064	3.2709
3 3/8	16	N-2A	0.5625	0.0017	3.3733	3.3639	0.0094	3.3327	3.3269	0.0058	3.2966
3 1/2	6	NS-2A	1.5000	0.0026	3.4974	3.4792	0.0182	3.3891	3.3804	0.0087	3.2929
3 1/2	7	NS-2A	1.2857	0.0024	3.4976	3.4812	0.0164	3.4048	3.3967	0.0081	3.3223
3 1/2	8	UN-2A	1.1250	0.0023	3.4977	3.4827	0.0150	3.4165	3.4089	0.0076	3.3443
3 1/2	10	NS-2A	0.9000	0.0021	3.4979	3.4850	0.0129	3.4329	3.4260	0.0069	3.3752
3 1/2	12	UN-2A	0.7500	0.0019	3.4981	3.4867	0.0114	3.4440	3.4376	0.0064	3.3959
3 1/2	14	NS-2A	0.6429	0.0018	3.4982	3.4879	0.0103	3.4518	3.4457	0.0061	3.4106
3 1/2	16	UN-2A	0.5625	0.0017	3.4983	3.4889	0.0094	3.4577	3.4519	0.0058	3.4216
3 1/2	18	NS-2A	0.5000	0.0017	3.4983	3.4896	0.0087	3.4622	3.4567	0.0055	3.4301
3 5/8	12	N-2A	0.7500	0.0019	3.6231	3.6117	0.0114	3.5690	3.5626	0.0064	3.5209
3 5/8	16	N-2A	0.5625	0.0017	3.6233	3.6139	0.0094	3.5827	3.5769	0.0058	3.5466
3 3/4	6	NS-2A	1.5000	0.0026	3.7474	3.7292	0.0182	3.6391	3.6304	0.0087	3.5429
3 3/4	7	NS-2A	1.2857	0.0024	3.7476	3.7312	0.0164	3.6548	3.6467	0.0081	3.5723
3 3/4	8	UN-2A	1.1250	0.0023	3.7477	3.7327	0.0150	3.6665	3.6589	0.0076	3.5943
3 3/4	10	NS-2A	0.9000	0.0021	3.7479	3.7350	0.0129	3.6829	3.6760	0.0069	3.6252
3 3/4	12	UN-2A	0.7500	0.0019	3.7481	3.7367	0.0114	3.6940	3.6876	0.0064	3.6459
3 3/4	14	NS-2A	0.6429	0.0018	3.7482	3.7379	0.0103	3.7018	3.6957	0.0061	3.6606
3 3/4	16	UN-2A	0.5625	0.0017	3.7483	3.7389	0.0094	3.7077	3.7019	0.0058	3.6716
3 3/4	18	NS-2A	0.5000	0.0017	3.7483	3.7396	0.0087	3.7122	3.7067	0.0055	3.6801
3 7/8	12	N-2A	0.7500	0.0020	3.8730	3.8616	0.0114	3.8189	3.8124	0.0065	3.7708
3 7/8	16	N-2A	0.5625	0.0018	3.8732	3.8638	0.0094	3.8326	3.8267	0.0059	3.7965
4	6	NS-2A	1.5000	0.0026	3.9974	3.9792	0.0182	3.8891	3.8803	0.0088	3.7929
4	7	NS-2A	1.2857	0.0024	3.9976	3.9812	0.0164	3.9048	3.8966	0.0082	3.8223
4	8	UN-2A	1.1250	0.0023	3.9977	3.9827	0.0150	3.9165	3.9088	0.0077	3.8443
4	10	NS-2A	0.9000	0.0021	3.9979	3.9850	0.0129	3.9329	3.9259	0.0070	3.8752
4	12	UN-2A	0.7500	0.0020	3.9980	3.9866	0.0114	3.9439	3.9374	0.0065	3.8958
4	14	NS-2A	0.6429	0.0018	3.9982	3.9879	0.0103	3.9518	3.9456	0.0062	3.9106
4	16	UN-2A	0.5625	0.0018	3.9982	3.9888	0.0094	3.9576	3.9517	0.0059	3.9215
4 1/4	4	UN-2A	2.2500	0.0032	4.2468	4.2230	0.0238	4.0844	4.0738	0.0106	3.9401
4 1/4	6	NS-2A	1.5000	0.0026	4.2474	4.2292	0.0182	4.1391	4.1303	0.0088	4.0429
4 1/4	7	NS-2A	1.2857	0.0025	4.2475	4.2311	0.0164	4.1547	4.1465	0.0082	4.0722
4 1/4	8	UN-2A	1.1250	0.0023	4.2477	4.2327	0.0150	4.1665	4.1588	0.0077	4.0943
4 1/4	10	NS-2A	0.9000	0.0021	4.2479	4.2350	0.0129	4.1829	4.1759	0.0070	4.1252
4 1/4	12	UN-2A	0.7500	0.0020	4.2480	4.2366	0.0114	4.1939	4.1874	0.0065	4.1458
4 1/4	14	NS-2A	0.6429	0.0018	4.2482	4.2379	0.0103	4.2018	4.1956	0.0062	4.1606
4 1/4	16	UN-2A	0.5625	0.0018	4.2482	4.2388	0.0094	4.2076	4.2017	0.0059	4.1715

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.
[c] See Fig. 1.
[d] Maximum limits are increased by the amount of the allowance for threads which are electroplated or have coatings of similar thicknesses. Where the allowance is not sufficient for the required thickness of plating or coating, special provisions are necessary.

TABLE 17f—*Class 2A, Selected Combinations of Special Diameter and Pitch—UN, N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE[a]							
					Major diameter			Pitch diameter[b]			
Size	Threads per inch	Thread symbol		Allowance	Limits		Tolerance	Limits		Tolerance	Minor diameter[c]
					Max[d]	Min		Max[d]	Min		
4½	4	UN-2A	2.2500	0.0032	4.4968	4.4730	0.0238	4.3344	4.3238	0.0106	4.1901
4½	6	NS-2A	1.5000	0.0026	4.4974	4.4792	0.0182	4.3891	4.3803	0.0088	4.2929
4½	7	NS-2A	1.2857	0.0025	4.4975	4.4811	0.0164	4.4047	4.3965	0.0082	4.3222
4½	8	UN-2A	1.1250	0.0023	4.4977	4.4827	0.0150	4.4165	4.4088	0.0077	4.3443
4½	10	NS-2A	0.9000	0.0021	4.4979	4.4850	0.0129	4.4329	4.4259	0.0070	4.3752
4½	12	UN-2A	0.7500	0.0020	4.4980	4.4866	0.0114	4.4439	4.4374	0.0065	4.3958
4½	14	NS-2A	0.6429	0.0018	4.4982	4.4879	0.0103	4.4518	4.4456	0.0062	4.4106
4½	16	UN-2A	0.5625	0.0018	4.4982	4.4888	0.0094	4.4576	4.4517	0.0059	4.4215
4¾	4	UN-2A	2.2500	0.0032	4.7468	4.7230	0.0238	4.5844	4.5736	0.0108	4.4401
4¾	6	NS-2A	1.5000	0.0027	4.7473	4.7291	0.0182	4.6390	4.6301	0.0089	4.5428
4¾	7	NS-2A	1.2857	0.0025	4.7475	4.7311	0.0164	4.6547	4.6463	0.0084	4.5722
4¾	8	UN-2A	1.1250	0.0024	4.7476	4.7326	0.0150	4.6664	4.6585	0.0079	4.5942
4¾	10	NS-2A	0.9000	0.0022	4.7478	4.7349	0.0129	4.6828	4.6756	0.0072	4.6251
4¾	12	UN-2A	0.7500	0.0020	4.7480	4.7366	0.0114	4.6939	4.6872	0.0067	4.6458
4¾	14	NS-2A	0.6429	0.0019	4.7481	4.7378	0.0103	4.7017	4.6953	0.0064	4.6605
4¾	16	UN-2A	0.5625	0.0018	4.7482	4.7388	0.0094	4.7076	4.7015	0.0061	4.6715
5	4	UN-2A	2.2500	0.0032	4.9968	4.9730	0.0238	4.8344	4.8236	0.0108	4.6901
5	6	NS-2A	1.5000	0.0027	4.9973	4.9791	0.0182	4.8890	4.8801	0.0089	4.7928
5	7	NS-2A	1.2857	0.0025	4.9975	4.9811	0.0164	4.9047	4.8963	0.0084	4.8222
5	8	UN-2A	1.1250	0.0024	4.9976	4.9826	0.0150	4.9164	4.9085	0.0079	4.8442
5	10	NS-2A	0.9000	0.0022	4.9978	4.9849	0.0129	4.9328	4.9256	0.0072	4.8751
5	12	UN-2A	0.7500	0.0020	4.9980	4.9866	0.0114	4.9439	4.9372	0.0067	4.8958
5	14	NS-2A	0.6429	0.0019	4.9981	4.9878	0.0103	4.9517	4.9453	0.0064	4.9105
5	16	UN-2A	0.5625	0.0018	4.9982	4.9888	0.0094	4.9576	4.9515	0.0061	4.9215
5¼	4	UN-2A	2.2500	0.0032	5.2468	5.2230	0.0238	5.0844	5.0736	0.0108	4.9401
5¼	6	NS-2A	1.5000	0.0027	5.2473	5.2291	0.0182	5.1390	5.1301	0.0089	5.0428
5¼	7	NS-2A	1.2857	0.0025	5.2475	5.2311	0.0164	5.1547	5.1463	0.0084	5.0722
5¼	8	UN-2A	1.1250	0.0024	5.2476	5.2326	0.0150	5.1664	5.1585	0.0079	5.0942
5¼	10	NS-2A	0.9000	0.0022	5.2478	5.2349	0.0129	5.1828	5.1756	0.0072	5.1251
5¼	12	UN-2A	0.7500	0.0020	5.2480	5.2366	0.0114	5.1939	5.1872	0.0067	5.1458
5¼	14	NS-2A	0.6429	0.0019	5.2481	5.2378	0.0103	5.2017	5.1953	0.0064	5.1605
5¼	16	UN-2A	0.5625	0.0018	5.2482	5.2388	0.0094	5.2076	5.2015	0.0061	5.1715
5½	4	UN-2A	2.2500	0.0032	5.4968	5.4730	0.0238	5.3344	5.3236	0.0108	5.1901
5½	6	NS-2A	1.5000	0.0027	5.4973	5.4791	0.0182	5.3890	5.3801	0.0089	5.2928
5½	7	NS-2A	1.2857	0.0025	5.4975	5.4811	0.0164	5.4047	5.3963	0.0084	5.3222
5½	8	UN-2A	1.1250	0.0024	5.4976	5.4826	0.0150	5.4164	5.4085	0.0079	5.3442
5½	10	NS-2A	0.9000	0.0022	5.4978	5.4849	0.0129	5.4328	5.4256	0.0072	5.3751
5½	12	UN-2A	0.7500	0.0020	5.4980	5.4866	0.0114	5.4439	5.4372	0.0067	5.3958
5½	14	NS-2A	0.6429	0.0019	5.4981	5.4878	0.0103	5.4517	5.4453	0.0064	5.4105
5½	16	UN-2A	0.5625	0.0018	5.4982	5.4888	0.0094	5.4576	5.4515	0.0061	5.4215
5¾	4	UN-2A	2.2500	0.0033	5.7467	5.7229	0.0238	5.5843	5.5734	0.0109	5.4400
5¾	6	NS-2A	1.5000	0.0027	5.7473	5.7291	0.0182	5.6390	5.6299	0.0091	5.5428
5¾	7	NS-2A	1.2857	0.0025	5.7475	5.7311	0.0164	5.6547	5.6462	0.0085	5.5722
5¾	8	UN-2A	1.1250	0.0024	5.7476	5.7326	0.0150	5.6664	5.6583	0.0081	5.5942
5¾	10	NS-2A	0.9000	0.0022	5.7478	5.7349	0.0129	5.6828	5.6754	0.0074	5.6251
5¾	12	UN-2A	0.7500	0.0021	5.7479	5.7365	0.0114	5.6938	5.6869	0.0069	5.6457
5¾	14	NS-2A	0.6429	0.0020	5.7480	5.7377	0.0103	5.7016	5.6951	0.0065	5.6604
5¾	16	UN-2A	0.5625	0.0019	5.7481	5.7387	0.0094	5.7075	5.7013	0.0062	5.6714
6	4	UN-2A	2.2500	0.0033	5.9967	5.9729	0.0238	5.8343	5.8234	0.0109	5.6900
6	6	NS-2A	1.5000	0.0027	5.9973	5.9791	0.0182	5.8890	5.8799	0.0091	5.7928
6	7	NS-2A	1.2857	0.0025	5.9975	5.9811	0.0164	5.9047	5.8962	0.0085	5.8222
6	8	UN-2A	1.1250	0.0024	5.9976	5.9826	0.0150	5.9164	5.9083	0.0081	5.8442
6	10	NS-2A	0.9000	0.0022	5.9978	5.9849	0.0129	5.9328	5.9254	0.0074	5.8751
6	12	UN-2A	0.7500	0.0021	5.9979	5.9865	0.0114	5.9438	5.9369	0.0069	5.8957
6	14	NS-2A	0.6429	0.0020	5.9980	5.9877	0.0103	5.9516	5.9451	0.0065	5.9104
6	16	UN-2A	0.5625	0.0019	5.9981	5.9887	0.0094	5.9575	5.9513	0.0062	5.9214

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.
[c] See Fig. 1.
[d] Maximum limits are increased by the amount of the allowance for threads which are electroplated or have coatings of similar thicknesses. Where the allowance is not sufficient for the required thickness of plating or coating, special provisions are necessary.

TABLE 18a—*Class 2B, Selected Combinations of Special Diameter and Pitch—UN, N, UNEF, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	INTERNAL-THREAD LIMITS OF SIZE[a]						
				Minor diameter			Pitch diameter[b]			Major diameter
				Limits		Tolerance	Limits		Tolerance	
Size	Threads per inch	Thread symbol		Min	Max		Min	Max		Min
10 (0.190)	28	NS-2B	0.3214	0.1513	0.1604	0.0091	0.1668	0.1711	0.0043	0.1900
10 (0.190)	36	NS-2B	0.2500	0.1599	0.1669	0.0070	0.1720	0.1759	0.0039	0.1900
10 (0.190)	40	NS-2B	0.2250	0.1629	0.1691	0.0062	0.1738	0.1775	0.0037	0.1900
10 (0.190)	48	NS-2B	0.1875	0.1674	0.1725	0.0051	0.1765	0.1799	0.0034	0.1900
10 (0.190)	56	NS-2B	0.1607	0.1707	0.1749	0.0042	0.1784	0.1816	0.0032	0.1900
12 (0.216)	32	NEF-2B	0.2812	0.1822	0.1895	0.0073	0.1957	0.1998	0.0041	0.2160
12 (0.216)	36	NS-2B	0.2500	0.1859	0.1923	0.0064	0.1980	0.2019	0.0039	0.2160
12 (0.216)	40	NS-2B	0.2250	0.1889	0.1946	0.0057	0.1998	0.2035	0.0037	0.2160
12 (0.216)	48	NS-2B	0.1875	0.1934	0.1981	0.0047	0.2025	0.2059	0.0034	0.2160
12 (0.216)	56	NS-2B	0.1607	0.1967	0.2006	0.0039	0.2044	0.2076	0.0032	0.2160
1/4	24	NS-2B	0.3750	0.2049	0.2139	0.0090	0.2229	0.2277	0.0048	0.2500
1/4	32	NEF-2B	0.2812	0.2162	0.2229	0.0067	0.2297	0.2339	0.0042	0.2500
1/4	36	UN-2B	0.2500	0.2199	0.2258	0.0059	0.2320	0.2360	0.0040	0.2500
1/4	40	NS-2B	0.2250	0.2229	0.2282	0.0053	0.2338	0.2376	0.0038	0.2500
1/4	48	NS-2B	0.1875	0.2274	0.2317	0.0043	0.2365	0.2401	0.0036	0.2500
1/4	56	NS-2B	0.1607	0.2307	0.2343	0.0036	0.2384	0.2417	0.0033	0.2500
5/16	20	NS-2B	0.4500	0.2584	0.2680	0.0096	0.2800	0.2852	0.0052	0.3125
5/16	28	NS-2B	0.3214	0.2738	0.2807	0.0069	0.2893	0.2937	0.0044	0.3125
5/16	32	NEF-2B	0.2812	0.2787	0.2847	0.0060	0.2922	0.2964	0.0042	0.3125
5/16	36	UN-2B	0.2500	0.2824	0.2877	0.0053	0.2945	0.2985	0.0040	0.3125
5/16	40	NS-2B	0.2250	0.2854	0.2902	0.0048	0.2963	0.3001	0.0038	0.3125
5/16	48	NS-2B	0.1875	0.2899	0.2940	0.0041	0.2990	0.3026	0.0036	0.3125
3/8	18	NS-2B	0.5000	0.3149	0.3246	0.0097	0.3389	0.3445	0.0056	0.3750
3/8	20	NS-2B	0.4500	0.3209	0.3297	0.0088	0.3425	0.3479	0.0054	0.3750
3/8	28	NS-2B	0.3214	0.3363	0.3426	0.0063	0.3518	0.3564	0.0046	0.3750
3/8	32	NEF-2B	0.2812	0.3412	0.3469	0.0057	0.3547	0.3591	0.0044	0.3750
3/8	36	UN-2B	0.2500	0.3449	0.3501	0.0052	0.3570	0.3612	0.0042	0.3750
3/8	40	NS-2B	0.2250	0.3479	0.3527	0.0048	0.3588	0.3628	0.0040	0.3750
7/16	16	NS-2B	0.5625	0.3698	0.3800	0.0102	0.3969	0.4028	0.0059	0.4375
7/16	18	NS-2B	0.5000	0.3774	0.3865	0.0091	0.4014	0.4070	0.0056	0.4375
7/16	24	NS-2B	0.3750	0.3924	0.3994	0.0070	0.4104	0.4153	0.0049	0.4375
7/16	28	UNEF-2B	0.3214	0.3988	0.4051	0.0063	0.4143	0.4189	0.0046	0.4375
7/16	32	NS-2B	0.2812	0.4037	0.4094	0.0057	0.4172	0.4216	0.0044	0.4375
1/2	14	NS-2B	0.6429	0.4227	0.4336	0.0109	0.4536	0.4601	0.0065	0.5000
1/2	16	NS-2B	0.5625	0.4323	0.4419	0.0096	0.4594	0.4655	0.0061	0.5000
1/2	18	NS-2B	0.5000	0.4399	0.4485	0.0086	0.4639	0.4697	0.0058	0.5000
1/2	24	NS-2B	0.3750	0.4549	0.4619	0.0070	0.4729	0.4780	0.0051	0.5000
1/2	28	UNEF-2B	0.3214	0.4613	0.4676	0.0063	0.4768	0.4816	0.0048	0.5000
1/2	32	NS-2B	0.2812	0.4662	0.4719	0.0057	0.4797	0.4842	0.0045	0.5000
9/16	14	NS-2B	0.6429	0.4852	0.4956	0.0104	0.5161	0.5226	0.0065	0.5625
9/16	16	NS-2B	0.5625	0.4948	0.5040	0.0092	0.5219	0.5280	0.0061	0.5625
9/16	20	NS-2B	0.4500	0.5084	0.5162	0.0078	0.5300	0.5355	0.0055	0.5625
9/16	24	NEF-2B	0.3750	0.5174	0.5244	0.0070	0.5354	0.5405	0.0051	0.5625
9/16	28	UN-2B	0.3214	0.5238	0.5301	0.0063	0.5393	0.5441	0.0048	0.5625
9/16	32	NS-2B	0.2812	0.5287	0.5344	0.0057	0.5422	0.5467	0.0045	0.5625
5/8	12	N-2B	0.7500	0.5348	0.5463	0.0115	0.5709	0.5780	0.0071	0.6250
5/8	14	NS-2B	0.6429	0.5477	0.5577	0.0100	0.5786	0.5852	0.0066	0.6250
5/8	16	NS-2B	0.5625	0.5573	0.5662	0.0089	0.5844	0.5906	0.0062	0.6250
5/8	20	NS-2B	0.4500	0.5709	0.5787	0.0078	0.5925	0.5981	0.0056	0.6250
5/8	24	NEF-2B	0.3750	0.5799	0.5869	0.0070	0.5979	0.6031	0.0052	0.6250
5/8	28	UN-2B	0.3214	0.5863	0.5926	0.0063	0.6018	0.6067	0.0049	0.6250
5/8	32	NS-2B	0.2812	0.5912	0.5969	0.0057	0.6047	0.6093	0.0046	0.6250
11/16	12	N-2B	0.7500	0.5973	0.6085	0.0112	0.6334	0.6405	0.0071	0.6875
11/16	24	NEF-2B	0.3750	0.6424	0.6494	0.0070	0.6604	0.6656	0.0052	0.6875

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.

TABLE 18b—*Class 2B, Selected Combinations of Special Diameter and Pitch—UN, N, UNEF, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	INTERNAL-THREAD LIMITS OF SIZE[a]						
				Minor diameter			Pitch diameter[b]			Major diameter
Size	Threads per inch	Thread symbol		Limits		Tolerance	Limits		Tolerance	
				Min	Max		Min	Max		Min
3/4	12	N-2B	0.7500	0.6598	0.6707	0.0109	0.6959	0.7031	0.0072	0.7500
3/4	14	NS-2B	0.6429	0.6727	0.6822	0.0095	0.7036	0.7103	0.0067	0.7500
3/4	18	NS-2B	0.5000	0.6899	0.6980	0.0081	0.7139	0.7199	0.0060	0.7500
3/4	20	UNEF-2B	0.4500	0.6959	0.7037	0.0078	0.7175	0.7232	0.0057	0.7500
3/4	24	NS-2B	0.3750	0.7049	0.7119	0.0070	0.7229	0.7282	0.0053	0.7500
3/4	28	UN-2B	0.3214	0.7113	0.7176	0.0063	0.7268	0.7318	0.0050	0.7500
3/4	32	NS-2B	0.2812	0.7162	0.7219	0.0057	0.7297	0.7344	0.0047	0.7500
13/16	12	N-2B	0.7500	0.7223	0.7329	0.0106	0.7584	0.7656	0.0072	0.8125
13/16	16	UN-2B	0.5625	0.7448	0.7533	0.0085	0.7719	0.7782	0.0063	0.8125
13/16	20	UNEF-2B	0.4500	0.7584	0.7662	0.0078	0.7800	0.7857	0.0057	0.8125
7/8	10	NS-2B	0.9000	0.7667	0.7789	0.0122	0.8100	0.8178	0.0078	0.8750
7/8	12	N-2B	0.7500	0.7848	0.7952	0.0104	0.8209	0.8281	0.0072	0.8750
7/8	16	UN-2B	0.5625	0.8073	0.8158	0.0085	0.8344	0.8407	0.0063	0.8750
7/8	18	NS-2B	0.5000	0.8149	0.8230	0.0081	0.8389	0.8449	0.0060	0.8750
7/8	20	UNEF-2B	0.4500	0.8209	0.8287	0.0078	0.8425	0.8482	0.0057	0.8750
7/8	24	NS-2B	0.3750	0.8299	0.8369	0.0070	0.8479	0.8532	0.0053	0.8750
7/8	28	UN-2B	0.3214	0.8363	0.8426	0.0063	0.8518	0.8568	0.0050	0.8750
7/8	32	NS-2B	0.2812	0.8412	0.8469	0.0057	0.8547	0.8594	0.0047	0.8750
15/16	12	UN-2B	0.7500	0.8473	0.8575	0.0102	0.8834	0.8908	0.0074	0.9375
15/16	16	UN-2B	0.5625	0.8698	0.8783	0.0085	0.8969	0.9034	0.0065	0.9375
15/16	20	UNEF-2B	0.4500	0.8834	0.8912	0.0078	0.9050	0.9109	0.0059	0.9375
1	10	NS-2B	0.9000	0.8917	0.9037	0.0120	0.9350	0.9430	0.0080	1.0000
1	16	UN-2B	0.5625	0.9323	0.9408	0.0085	0.9594	0.9659	0.0065	1.0000
1	18	NS-2B	0.5000	0.9399	0.9480	0.0081	0.9639	0.9701	0.0062	1.0000
1	20	UNEF-2B	0.4500	0.9459	0.9537	0.0078	0.9675	0.9734	0.0059	1.0000
1	24	NS-2B	0.3750	0.9549	0.9619	0.0070	0.9729	0.9784	0.0055	1.0000
1	28	UN-2B	0.3214	0.9613	0.9676	0.0063	0.9768	0.9820	0.0052	1.0000
1	32	NS-2B	0.2812	0.9662	0.9719	0.0057	0.9797	0.9846	0.0049	1.0000
1 1/16	12	UN-2B	0.7500	0.9723	0.9823	0.0100	1.0084	1.0158	0.0074	1.0625
1 1/16	16	UN-2B	0.5625	0.9948	1.0033	0.0085	1.0219	1.0284	0.0065	1.0625
1 1/16	18	NEF-2B	0.5000	1.0024	1.0105	0.0081	1.0264	1.0326	0.0062	1.0625
1 1/8	10	NS-2B	0.9000	1.0167	1.0287	0.0120	1.0600	1.0680	0.0080	1.1250
1 1/8	14	NS-2B	0.6429	1.0477	1.0565	0.0088	1.0786	1.0855	0.0069	1.1250
1 1/8	16	UN-2B	0.5625	1.0573	1.0658	0.0085	1.0844	1.0910	0.0066	1.1250
1 1/8	18	NEF-2B	0.5000	1.0649	1.0730	0.0081	1.0889	1.0951	0.0062	1.1250
1 1/8	20	UN-2B	0.4500	1.0709	1.0787	0.0078	1.0925	1.0984	0.0059	1.1250
1 1/8	24	NS-2B	0.3750	1.0799	1.0869	0.0070	1.0979	1.1034	0.0055	1.1250
1 1/8	28	UN-2B	0.3214	1.0863	1.0926	0.0063	1.1018	1.1070	0.0052	1.1250
1 3/16	12	UN-2B	0.7500	1.0973	1.1073	0.0100	1.1334	1.1409	0.0075	1.1875
1 3/16	16	UN-2B	0.5625	1.1198	1.1283	0.0085	1.1469	1.1535	0.0066	1.1875
1 3/16	18	NEF-2B	0.5000	1.1274	1.1355	0.0081	1.1514	1.1577	0.0063	1.1875
1 1/4	10	NS-2B	0.9000	1.1417	1.1537	0.0120	1.1850	1.1932	0.0082	1.2500
1 1/4	14	NS-2B	0.6429	1.1727	1.1815	0.0088	1.2036	1.2106	0.0070	1.2500
1 1/4	16	UN-2B	0.5625	1.1823	1.1908	0.0085	1.2094	1.2160	0.0066	1.2500
1 1/4	18	NEF-2B	0.5000	1.1899	1.1980	0.0081	1.2139	1.2202	0.0063	1.2500
1 1/4	20	UN-2B	0.4500	1.1959	1.2037	0.0078	1.2175	1.2236	0.0061	1.2500
1 1/4	24	NS-2B	0.3750	1.2049	1.2119	0.0070	1.2229	1.2285	0.0056	1.2500
1 5/16	12	UN-2B	0.7500	1.2223	1.2323	0.0100	1.2584	1.2659	0.0075	1.3125
1 5/16	16	UN-2B	0.5625	1.2448	1.2533	0.0085	1.2719	1.2785	0.0066	1.3125
1 5/16	18	NEF-2B	0.5000	1.2524	1.2605	0.0081	1.2764	1.2827	0.0063	1.3125

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.

TABLE 18c—*Class 2B, Selected Combinations of Special Diameter and Pitch—UN, N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	INTERNAL-THREAD LIMITS OF SIZE[a]						
				Minor diameter			Pitch diameter[b]			Major diameter
				Limits		Tolerance	Limits		Tolerance	
Size	Threads per inch	Thread symbol		Min	Max		Min	Max		Min
1⅜	10	NS-2B	0.9000	1.2667	1.2787	0.0120	1.3100	1.3182	0.0082	1.3750
1⅜	14	NS-2B	0.6429	1.2977	1.3065	0.0088	1.3286	1.3356	0.0070	1.3750
1⅜	16	UN-2B	0.5625	1.3073	1.3158	0.0085	1.3344	1.3410	0.0066	1.3750
1⅜	18	NEF-2B	0.5000	1.3149	1.3230	0.0081	1.3389	1.3452	0.0063	1.3750
1⁷⁄₁₆	12	UN-2B	0.7500	1.3473	1.3573	0.0100	1.3834	1.3910	0.0076	1.4375
1⁷⁄₁₆	16	UN-2B	0.5625	1.3698	1.3783	0.0085	1.3969	1.4037	0.0068	1.4375
1⁷⁄₁₆	18	NEF-2B	0.5000	1.3774	1.3855	0.0081	1.4014	1.4079	0.0065	1.4375
1½	10	NS-2B	0.9000	1.3917	1.4037	0.0120	1.4350	1.4433	0.0083	1.5000
1½	14	NS-2B	0.6429	1.4227	1.4315	0.0088	1.4536	1.4608	0.0072	1.5000
1½	16	UN-2B	0.5625	1.4323	1.4408	0.0085	1.4594	1.4662	0.0068	1.5000
1½	18	NEF-2B	0.5000	1.4399	1.4480	0.0081	1.4639	1.4704	0.0065	1.5000
1½	20	UN-2B	0.4500	1.4459	1.4537	0.0078	1.4675	1.4737	0.0062	1.5000
1½	24	NS-2B	0.3750	1.4549	1.4619	0.0070	1.4729	1.4787	0.0058	1.5000
1⁹⁄₁₆	16	N-2B	0.5625	1.4948	1.5033	0.0085	1.5219	1.5287	0.0068	1.5625
1⁹⁄₁₆	18	NEF-2B	0.5000	1.5024	1.5105	0.0081	1.5264	1.5329	0.0065	1.5625
1⅝	6	NS-2B	1.5000	1.4446	1.4646	0.0200	1.5167	1.5272	0.0105	1.6250
1⅝	7	NS-2B	1.2857	1.4704	1.4875	0.0171	1.5322	1.5420	0.0098	1.6250
1⅝	10	NS-2B	0.9000	1.5167	1.5287	0.0120	1.5600	1.5683	0.0083	1.6250
1⅝	12	N-2B	0.7500	1.5348	1.5448	0.0100	1.5709	1.5785	0.0076	1.6250
1⅝	14	NS-2B	0.6429	1.5477	1.5565	0.0088	1.5786	1.5858	0.0072	1.6250
1⅝	16	N-2B	0.5625	1.5573	1.5658	0.0085	1.5844	1.5912	0.0068	1.6250
1⅝	18	NEF-2B	0.5000	1.5649	1.5730	0.0081	1.5889	1.5954	0.0065	1.6250
1⅝	20	NS-2B	0.4500	1.5709	1.5787	0.0078	1.5925	1.5987	0.0062	1.6250
1⅝	24	NS-2B	0.3750	1.5799	1.5869	0.0070	1.5979	1.6037	0.0058	1.6250
1¹¹⁄₁₆	16	N-2B	0.5625	1.6198	1.6283	0.0085	1.6469	1.6538	0.0069	1.6875
1¹¹⁄₁₆	18	NEF-2B	0.5000	1.6274	1.6355	0.0081	1.6514	1.6580	0.0066	1.6875
1¾	6	NS-2B	1.5000	1.5696	1.5896	0.0200	1.6417	1.6523	0.0106	1.7500
1¾	7	NS-2B	1.2857	1.5954	1.6125	0.0171	1.6572	1.6671	0.0099	1.7500
1¾	8	UN-2B	1.1250	1.6147	1.6297	0.0150	1.6688	1.6781	0.0093	1.7500
1¾	10	NS-2B	0.9000	1.6417	1.6537	0.0120	1.6850	1.6934	0.0084	1.7500
1¾	12	UN-2B	0.7500	1.6598	1.6698	0.0100	1.6959	1.7037	0.0078	1.7500
1¾	14	NS-2B	0.6429	1.6727	1.6815	0.0088	1.7036	1.7109	0.0073	1.7500
1¾	16	UNEF-2B	0.5625	1.6823	1.6908	0.0085	1.7094	1.7163	0.0069	1.7500
1¾	18	NS-2B	0.5000	1.6899	1.6980	0.0081	1.7139	1.7205	0.0066	1.7500
1¾	20	UN-2B	0.4500	1.6959	1.7037	0.0078	1.7175	1.7238	0.0063	1.7500
1¹³⁄₁₆	16	N-2B	0.5625	1.7448	1.7533	0.0085	1.7719	1.7788	0.0069	1.8125
1⅞	6	NS-2B	1.5000	1.6946	1.7146	0.0200	1.7667	1.7773	0.0106	1.8750
1⅞	7	NS-2B	1.2857	1.7204	1.7375	0.0171	1.7822	1.7921	0.0099	1.8750
1⅞[c]	8	NS-2B	1.1250	1.7397	1.7547	0.0150	1.7938	1.8031	0.0093	1.8750
1⅞	10	NS-2B	0.9000	1.7667	1.7787	0.0120	1.8100	1.8184	0.0084	1.8750
1⅞	12	N-2B	0.7500	1.7848	1.7948	0.0100	1.8209	1.8287	0.0078	1.8750
1⅞	14	NS-2B	0.6429	1.7977	1.8065	0.0088	1.8286	1.8359	0.0073	1.8750
1⅞	16	N-2B	0.5625	1.8073	1.8158	0.0085	1.8344	1.8413	0.0069	1.8750
1⅞	18	NS-2B	0.5000	1.8149	1.8230	0.0081	1.8389	1.8455	0.0066	1.8750
1⅞	20	NS-2B	0.4500	1.8209	1.8287	0.0078	1.8425	1.8488	0.0063	1.8750
1¹⁵⁄₁₆	16	N-2B	0.5625	1.8698	1.8783	0.0085	1.8969	1.9039	0.0070	1.9375

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.
[c] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 18d—*Class 2B, Selected Combinations of Special Diameter and Pitch—UN, N, NEF, and NS*

DESIGNATION				INTERNAL-THREAD LIMITS OF SIZE[a]					
				Minor diameter			Pitch diameter[b]			Major diameter
				Limits		Tolerance	Limits		Tolerance	
Size	Threads per inch	Thread symbol	L_e, 9 × PITCH	Min	Max		Min	Max		Min
2	6	NS-2B	1.5000	1.8196	1.8396	0.0200	1.8917	1.9025	0.0108	2.0000
2	7	NS-2B	1.2857	1.8454	1.8625	0.0171	1.9072	1.9172	0.0100	2.0000
2	8	UN-2B	1.1250	1.8647	1.8797	0.0150	1.9188	1.9282	0.0094	2.0000
2	10	NS-2B	0.9000	1.8917	1.9037	0.0120	1.9350	1.9435	0.0085	2.0000
2	12	UN-2B	0.7500	1.9098	1.9198	0.0100	1.9459	1.9538	0.0079	2.0000
2	14	NS-2B	0.6429	1.9227	1.9315	0.0088	1.9536	1.9610	0.0074	2.0000
2	16	UNEF-2B	0.5625	1.9323	1.9408	0.0085	1.9594	1.9664	0.0070	2.0000
2	18	NS-2B	0.5000	1.9399	1.9480	0.0081	1.9639	1.9706	0.0067	2.0000
2	20	UN-2B	0.4500	1.9459	1.9537	0.0078	1.9675	1.9739	0.0064	2.0000
2 1/16	16	N-2B	0.5625	1.9948	2.0033	0.0085	2.0219	2.0289	0.0070	2.0625
2 1/8	12	N-2B	0.7500	2.0348	2.0448	0.0100	2.0709	2.0788	0.0079	2.1250
2 1/8	16	N-2B	0.5625	2.0573	2.0658	0.0085	2.0844	2.0914	0.0070	2.1250
2 3/16	16	N-2B	0.5625	2.1198	2.1283	0.0085	2.1469	2.1539	0.0070	2.1875
2 1/4	6	NS-2B	1.5000	2.0696	2.0896	0.0200	2.1417	2.1525	0.0108	2.2500
2 1/4	7	NS-2B	1.2857	2.0954	2.1125	0.0171	2.1572	2.1672	0.0100	2.2500
2 1/4	8	UN-2B	1.1250	2.1147	2.1297	0.0150	2.1688	2.1782	0.0094	2.2500
2 1/4	10	NS-2B	0.9000	2.1417	2.1537	0.0120	2.1850	2.1935	0.0085	2.2500
2 1/4	12	UN-2B	0.7500	2.1598	2.1698	0.0100	2.1959	2.2038	0.0079	2.2500
2 1/4	14	NS-2B	0.6429	2.1727	2.1815	0.0088	2.2036	2.2110	0.0074	2.2500
2 1/4	16	UN-2B	0.5625	2.1823	2.1908	0.0085	2.2094	2.2164	0.0070	2.2500
2 1/4	18	NS-2B	0.5000	2.1899	2.1980	0.0081	2.2139	2.2206	0.0067	2.2500
2 1/4	20	UN-2B	0.4500	2.1959	2.2037	0.0078	2.2175	2.2239	0.0064	2.2500
2 5/16	16	N-2B	0.5625	2.2448	2.2533	0.0085	2.2719	2.2791	0.0072	2.3125
2 3/8	12	N-2B	0.7500	2.2848	2.2948	0.0100	2.3209	2.3290	0.0081	2.3750
2 3/8	16	N-2B	0.5625	2.3073	2.3158	0.0085	2.3344	2.3416	0.0072	2.3750
2 7/16	16	N-2B	0.5625	2.3698	2.3783	0.0085	2.3969	2.4041	0.0072	2.4375
2 1/2	6	NS-2B	1.5000	2.3196	2.3396	0.0200	2.3917	2.4026	0.0109	2.5000
2 1/2	7	NS-2B	1.2857	2.3454	2.3625	0.0171	2.4072	2.4174	0.0102	2.5000
2 1/2	8	UN-2B	1.1250	2.3647	2.3797	0.0150	2.4188	2.4284	0.0096	2.5000
2 1/2	10	NS-2B	0.9000	2.3917	2.4037	0.0120	2.4350	2.4437	0.0087	2.5000
2 1/2	12	UN-2B	0.7500	2.4098	2.4198	0.0100	2.4459	2.4540	0.0081	2.5000
2 1/2	14	NS-2B	0.6429	2.4227	2.4315	0.0088	2.4536	2.4612	0.0076	2.5000
2 1/2	16	UN-2B	0.5625	2.4323	2.4408	0.0085	2.4594	2.4666	0.0072	2.5000
2 1/2	18	NS-2B	0.5000	2.4399	2.4480	0.0081	2.4639	2.4708	0.0069	2.5000
2 1/2	20	UN-2B	0.4500	2.4459	2.4537	0.0078	2.4675	2.4741	0.0066	2.5000
2 5/8	12	N-2B	0.7500	2.5348	2.5448	0.0100	2.5709	2.5790	0.0081	2.6250
2 5/8	16	N-2B	0.5625	2.5573	2.5658	0.0085	2.5844	2.5916	0.0072	2.6250
2 3/4	6	NS-2B	1.5000	2.5696	2.5896	0.0200	2.6417	2.6526	0.0109	2.7500
2 3/4	7	NS-2B	1.2857	2.5954	2.6125	0.0171	2.6572	2.6674	0.0102	2.7500
2 3/4	8	UN-2B	1.1250	2.6147	2.6297	0.0150	2.6688	2.6784	0.0096	2.7500
2 3/4	10	NS-2B	0.9000	2.6417	2.6537	0.0120	2.6850	2.6937	0.0087	2.7500
2 3/4	12	UN-2B	0.7500	2.6598	2.6698	0.0100	2.6959	2.7040	0.0081	2.7500
2 3/4	14	NS-2B	0.6429	2.6727	2.6815	0.0088	2.7036	2.7112	0.0076	2.7500
2 3/4	16	UN-2B	0.5625	2.6823	2.6908	0.0085	2.7094	2.7166	0.0072	2.7500
2 3/4	18	NS-2B	0.5000	2.6899	2.6980	0.0081	2.7139	2.7208	0.0069	2.7500
2 7/8	12	N-2B	0.7500	2.7848	2.7948	0.0100	2.8209	2.8291	0.0082	2.8750
2 7/8	16	N-2B	0.5625	2.8073	2.8158	0.0085	2.8344	2.8417	0.0073	2.8750

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.

TABLE 18e—*Class 2B, Selected Combinations of Special Diameter and Pitch—UN, N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	INTERNAL-THREAD LIMITS OF SIZE[a]						
				Minor diameter			Pitch diameter[b]			Major diameter
				Limits		Tolerance	Limits		Tolerance	
Size	Threads per inch	Thread symbol		Min	Max		Min	Max		Min
3	6	NS-2B	1.5000	2.8196	2.8396	0.0200	2.8917	2.9028	0.0111	3.0000
3	7	NS-2B	1.2857	2.8454	2.8625	0.0171	2.9072	2.9176	0.0104	3.0000
3	8	UN-2B	1.1250	2.8647	2.8797	0.0150	2.9188	2.9286	0.0098	3.0000
3	10	NS-2B	0.9000	2.8917	2.9037	0.0120	2.9350	2.9439	0.0089	3.0000
3	12	UN-2B	0.7500	2.9098	2.9198	0.0100	2.9459	2.9541	0.0082	3.0000
3	14	NS-2B	0.6429	2.9227	2.9315	0.0088	2.9536	2.9613	0.0077	3.0000
3	16	UN-2B	0.5625	2.9323	2.9408	0.0085	2.9594	2.9667	0.0073	3.0000
3	18	NS-2B	0.5000	2.9399	2.9480	0.0081	2.9639	2.9709	0.0070	3.0000
3 1/8	12	N-2B	0.7500	3.0348	3.0448	0.0100	3.0709	3.0791	0.0082	3.1250
3 1/8	16	N-2B	0.5625	3.0573	3.0658	0.0085	3.0844	3.0917	0.0073	3.1250
3 1/4	6	NS-2B	1.5000	3.0696	3.0896	0.0200	3.1417	3.1528	0.0111	3.2500
3 1/4	7	NS-2B	1.2857	3.0954	3.1125	0.0171	3.1572	3.1676	0.0104	3.2500
3 1/4	8	UN-2B	1.1250	3.1147	3.1297	0.0150	3.1688	3.1786	0.0098	3.2500
3 1/4	10	NS-2B	0.9000	3.1417	3.1537	0.0120	3.1850	3.1939	0.0089	3.2500
3 1/4	12	UN-2B	0.7500	3.1598	3.1698	0.0100	3.1959	3.2041	0.0082	3.2500
3 1/4	14	NS-2B	0.6429	3.1727	3.1815	0.0088	3.2036	3.2113	0.0077	3.2500
3 1/4	16	UN-2B	0.5625	3.1823	3.1908	0.0085	3.2094	3.2167	0.0073	3.2500
3 1/4	18	NS-2B	0.5000	3.1899	3.1980	0.0081	3.2139	3.2209	0.0070	3.2500
3 3/8	12	N-2B	0.7500	3.2848	3.2948	0.0100	3.3209	3.3293	0.0084	3.3750
3 3/8	16	N-2B	0.5625	3.3073	3.3158	0.0085	3.3344	3.3419	0.0075	3.3750
3 1/2	6	NS-2B	1.5000	3.3196	3.3396	0.0200	3.3917	3.4030	0.0113	3.5000
3 1/2	7	NS-2B	1.2857	3.3454	3.3625	0.0171	3.4072	3.4177	0.0105	3.5000
3 1/2	8	UN-2B	1.1250	3.3647	3.3797	0.0150	3.4188	3.4287	0.0099	3.5000
3 1/2	10	NS-2B	0.9000	3.3917	3.4037	0.0120	3.4350	3.4440	0.0090	3.5000
3 1/2	12	UN-2B	0.7500	3.4098	3.4198	0.0100	3.4459	3.4543	0.0084	3.5000
3 1/2	14	NS-2B	0.6429	3.4227	3.4315	0.0088	3.4536	3.4615	0.0079	3.5000
3 1/2	16	UN-2B	0.5625	3.4323	3.4408	0.0085	3.4594	3.4669	0.0075	3.5000
3 1/2	18	NS-2B	0.5000	3.4399	3.4480	0.0081	3.4639	3.4711	0.0072	3.5000
3 5/8	12	N-2B	0.7500	3.5348	3.5448	0.0100	3.5709	3.5793	0.0084	3.6250
3 5/8	16	N-2B	0.5625	3.5573	3.5658	0.0085	3.5844	3.5919	0.0075	3.6250
3 3/4	6	NS-2B	1.5000	3.5696	3.5896	0.0200	3.6417	3.6530	0.0113	3.7500
3 3/4	7	NS-2B	1.2857	3.5954	3.6125	0.0171	3.6572	3.6677	0.0105	3.7500
3 3/4	8	UN-2B	1.1250	3.6147	3.6297	0.0150	3.6688	3.6787	0.0099	3.7500
3 3/4	10	NS-2B	0.9000	3.6417	3.6537	0.0120	3.6850	3.6940	0.0090	3.7500
3 3/4	12	UN-2B	0.7500	3.6598	3.6698	0.0100	3.6959	3.7043	0.0084	3.7500
3 3/4	14	NS-2B	0.6429	3.6727	3.6815	0.0088	3.7036	3.7115	0.0079	3.7500
3 3/4	16	UN-2B	0.5625	3.6823	3.6908	0.0085	3.7094	3.7169	0.0075	3.7500
3 3/4	18	NS-2B	0.5000	3.6899	3.6980	0.0081	3.7139	3.7211	0.0072	3.7500
3 7/8	12	N-2B	0.7500	3.7848	3.7948	0.0100	3.8209	3.8294	0.0085	3.8750
3 7/8	16	N-2B	0.5625	3.8073	3.8158	0.0085	3.8344	3.8420	0.0076	3.8750
4	6	NS-2B	1.5000	3.8196	3.8396	0.0200	3.8917	3.9031	0.0114	4.0000
4	7	NS-2B	1.2857	3.8454	3.8625	0.0171	3.9072	3.9178	0.0106	4.0000
4	8	UN-2B	1.1250	3.8647	3.8797	0.0150	3.9188	3.9288	0.0100	4.0000
4	10	NS-2B	0.9000	3.8917	3.9037	0.0120	3.9350	3.9441	0.0091	4.0000
4	12	UN-2B	0.7500	3.9098	3.9198	0.0100	3.9459	3.9544	0.0085	4.0000
4	14	NS-2B	0.6429	3.9227	3.9315	0.0088	3.9536	3.9616	0.0080	4.0000
4	16	UN-2B	0.5625	3.9323	3.9408	0.0085	3.9594	3.9670	0.0076	4.0000
4 1/4	4	UN-2B	2.2500	3.9794	4.0094	0.0300	4.0876	4.1014	0.0138	4.2500
4 1/4	6	NS-2B	1.5000	4.0696	4.0896	0.0200	4.1417	4.1531	0.0114	4.2500
4 1/4	7	NS-2B	1.2857	4.0954	4.1125	0.0171	4.1572	4.1678	0.0106	4.2500
4 1/4	8	UN-2B	1.1250	4.1147	4.1297	0.0150	4.1688	4.1788	0.0100	4.2500
4 1/4	10	NS-2B	0.9000	4.1417	4.1537	0.0120	4.1850	4.1941	0.0091	4.2500
4 1/4	12	UN-2B	0.7500	4.1598	4.1698	0.0100	4.1959	4.2044	0.0085	4.2500
4 1/4	14	NS-2B	0.6429	4.1727	4.1815	0.0088	4.2036	4.2116	0.0080	4.2500
4 1/4	16	UN-2B	0.5625	4.1823	4.1908	0.0085	4.2094	4.2170	0.0076	4.2500

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.

TABLE 18f—*Class 2B, Selected Combinations of Special Diameter and Pitch—UN, N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	INTERNAL-THREAD LIMITS OF SIZE[a]						
				Minor diameter			Pitch diameter[b]			Major diameter
				Limits		Tolerance	Limits		Tolerance	
Size	Threads per inch	Thread symbol		Min	Max		Min	Max		Min
4½	4	UN-2B	2.2500	4.2294	4.2594	0.0300	4.3376	4.3514	0.0138	4.5000
4½	6	NS-2B	1.5000	4.3196	4.3396	0.0200	4.3917	4.4031	0.0114	4.5000
4½	7	NS-2B	1.2857	4.3454	4.3625	0.0171	4.4072	4.4178	0.0106	4.5000
4½	8	UN-2B	1.1250	4.3647	4.3797	0.0150	4.4188	4.4288	0.0100	4.5000
4½	10	NS-2B	0.9000	4.3917	4.4037	0.0120	4.4350	4.4441	0.0091	4.5000
4½	12	UN-2B	0.7500	4.4098	4.4198	0.0100	4.4459	4.4544	0.0085	4.5000
4½	14	NS-2B	0.6429	4.4227	4.4315	0.0088	4.4536	4.4616	0.0080	4.5000
4½	16	UN-2B	0.5625	4.4323	4.4408	0.0085	4.4594	4.4670	0.0076	4.5000
4¾	4	UN-2B	2.2500	4.4794	4.5094	0.0300	4.5876	4.6016	0.0140	4.7500
4¾	6	NS-2B	1.5000	4.5696	4.5896	0.0200	4.6417	4.6533	0.0116	4.7500
4¾	7	NS-2B	1.2857	4.5954	4.6125	0.0171	4.6572	4.6681	0.0109	4.7500
4¾	8	UN-2B	1.1250	4.6147	4.6297	0.0150	4.6688	4.6791	0.0103	4.7500
4¾	10	NS-2B	0.9000	4.6417	4.6537	0.0120	4.6850	4.6944	0.0094	4.7500
4¾	12	UN-2B	0.7500	4.6598	4.6698	0.0100	4.6959	4.7046	0.0087	4.7500
4¾	14	NS-2B	0.6429	4.6727	4.6815	0.0088	4.7036	4.7119	0.0083	4.7500
4¾	16	UN-2B	0.5625	4.6823	4.6908	0.0085	4.7094	4.7173	0.0079	4.7500
5	4	UN-2B	2.2500	4.7294	4.7594	0.0300	4.8376	4.8516	0.0140	5.0000
5	6	NS-2B	1.5000	4.8196	4.8396	0.0200	4.8917	4.9033	0.0116	5.0000
5	7	NS-2B	1.2857	4.8454	4.8625	0.0171	4.9072	4.9181	0.0109	5.0000
5	8	UN-2B	1.1250	4.8647	4.8797	0.0150	4.9188	4.9291	0.0103	5.0000
5	10	NS-2B	0.9000	4.8917	4.9037	0.0120	4.9350	4.9444	0.0094	5.0000
5	12	UN-2B	0.7500	4.9098	4.9198	0.0100	4.9459	4.9546	0.0087	5.0000
5	14	NS-2B	0.6429	4.9227	4.9315	0.0088	4.9536	4.9619	0.0083	5.0000
5	16	UN-2B	0.5625	4.9323	4.9408	0.0085	4.9594	4.9673	0.0079	5.0000
5¼	4	UN-2B	2.2500	4.9794	5.0094	0.0300	5.0876	5.1016	0.0140	5.2500
5¼	6	NS-2B	1.5000	5.0696	5.0896	0.0200	5.1417	5.1533	0.0116	5.2500
5¼	7	NS-2B	1.2857	5.0954	5.1125	0.0171	5.1572	5.1681	0.0109	5.2500
5¼	8	UN-2B	1.1250	5.1147	5.1297	0.0150	5.1688	5.1791	0.0103	5.2500
5¼	10	NS-2B	0.9000	5.1417	5.1537	0.0120	5.1850	5.1944	0.0094	5.2500
5¼	12	UN-2B	0.7500	5.1598	5.1698	0.0100	5.1959	5.2046	0.0087	5.2500
5¼	14	NS-2B	0.6429	5.1727	5.1815	0.0088	5.2036	5.2119	0.0083	5.2500
5¼	16	UN-2B	0.5625	5.1823	5.1908	0.0085	5.2094	5.2173	0.0079	5.2500
5½	4	UN-2B	2.2500	5.2294	5.2594	0.0300	5.3376	5.3516	0.0140	5.5000
5½	6	NS-2B	1.5000	5.3196	5.3396	0.0200	5.3917	5.4033	0.0116	5.5000
5½	7	NS-2B	1.2857	5.3454	5.3625	0.0171	5.4072	5.4181	0.0109	5.5000
5½	8	UN-2B	1.1250	5.3647	5.3797	0.0150	5.4188	5.4291	0.0103	5.5000
5½	10	NS-2B	0.9000	5.3917	5.4037	0.0120	5.4350	5.4444	0.0094	5.5000
5½	12	UN-2B	0.7500	5.4098	5.4198	0.0100	5.4459	5.4546	0.0087	5.5000
5½	14	NS-2B	0.6429	5.4227	5.4315	0.0088	5.4536	5.4619	0.0083	5.5000
5½	16	UN-2B	0.5625	5.4323	5.4408	0.0085	5.4594	5.4673	0.0079	5.5000
5¾	4	UN-2B	2.2500	5.4794	5.5094	0.0300	5.5876	5.6018	0.0142	5.7500
5¾	6	NS-2B	1.5000	5.5696	5.5896	0.0200	5.6417	5.6535	0.0118	5.7500
5¾	7	NS-2B	1.2857	5.5954	5.6125	0.0171	5.6572	5.6683	0.0111	5.7500
5¾	8	UN-2B	1.1250	5.6147	5.6297	0.0150	5.6688	5.6793	0.0105	5.7500
5¾	10	NS-2B	0.9000	5.6417	5.6537	0.0120	5.6850	5.6946	0.0096	5.7500
5¾	12	UN-2B	0.7500	5.6598	5.6698	0.0100	5.6959	5.7049	0.0090	5.7500
5¾	14	NS-2B	0.6429	5.6727	5.6815	0.0088	5.7036	5.7121	0.0085	5.7500
5¾	16	UN-2B	0.5625	5.6823	5.6908	0.0085	5.7094	5.7175	0.0081	5.7500
6	4	UN-2B	2.2500	5.7294	5.7594	0.0300	5.8376	5.8518	0.0142	6.0000
6	6	NS-2B	1.5000	5.8196	5.8396	0.0200	5.8917	5.9035	0.0118	6.0000
6	7	NS-2B	1.2857	5.8454	5.8625	0.0171	5.9072	5.9183	0.0111	6.0000
6	8	UN-2B	1.1250	5.8647	5.8797	0.0150	5.9188	5.9293	0.0105	6.0000
6	10	NS-2B	0.9000	5.8917	5.9037	0.0120	5.9350	5.9446	0.0096	6.0000
6	12	UN-2B	0.7500	5.9098	5.9198	0.0100	5.9459	5.9549	0.0090	6.0000
6	14	NS-2B	0.6429	5.9227	5.9315	0.0088	5.9536	5.9621	0.0085	6.0000
6	16	UN-2B	0.5625	5.9323	5.9408	0.0085	5.9594	5.9675	0.0081	6.0000

[a] Applicable to lengths of engagement of from 5 to 15 times the pitch, inclusive.
[b] British: Effective Diameter.

TABLE 19a—*Class 2, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
10 (0.190)	28	NS-2	0.3214	0.1900	0.1838	0.1668	0.1636	0.1462	0.1513	0.1596	0.1668	0.1700	0.1900
10 (0.190)	36	NS-2	0.2500	0.1900	0.1850	0.1720	0.1691	0.1559	0.1599	0.1646	0.1720	0.1749	0.1900
10 (0.190)	40	NS-2	0.2250	0.1900	0.1852	0.1738	0.1711	0.1593	0.1629	0.1668	0.1738	0.1765	0.1900
10 (0.190)	48	NS-2	0.1875	0.1900	0.1856	0.1765	0.1739	0.1644	0.1674	0.1707	0.1765	0.1791	0.1900
10 (0.190)	56	NS-2	0.1607	0.1900	0.1860	0.1784	0.1760	0.1681	0.1707	0.1738	0.1784	0.1808	0.1900
12 (0.216)	32	NEF-2	0.2812	0.2160	0.2106	0.1957	0.1926	0.1777	0.1822	0.1875	0.1957	0.1988	0.2160
12 (0.216)	36	NS-2	0.2500	0.2160	0.2110	0.1980	0.1951	0.1819	0.1859	0.1901	0.1980	0.2009	0.2160
12 (0.216)	40	NS-2	0.2250	0.2160	0.2112	0.1998	0.1971	0.1853	0.1889	0.1927	0.1998	0.2025	0.2160
12 (0.216)	48	NS-2	0.1875	0.2160	0.2116	0.2025	0.1999	0.1904	0.1934	0.1967	0.2025	0.2051	0.2160
12 (0.216)	56	NS-2	0.1607	0.2160	0.2120	0.2044	0.2020	0.1941	0.1967	0.1998	0.2044	0.2068	0.2160
1/4	24	NS-2	0.3750	0.2500	0.2434	0.2229	0.2194	0.1989	0.2049	0.2126	0.2229	0.2264	0.2500
1/4	32	NEF-2	0.2812	0.2500	0.2446	0.2297	0.2265	0.2117	0.2162	0.2210	0.2297	0.2329	0.2500
1/4	36	NS-2	0.2500	0.2500	0.2450	0.2320	0.2290	0.2159	0.2199	0.2241	0.2320	0.2350	0.2500
1/4	40	NS-2	0.2250	0.2500	0.2452	0.2338	0.2309	0.2193	0.2229	0.2267	0.2338	0.2367	0.2500
1/4	48	NS-2	0.1875	0.2500	0.2456	0.2365	0.2338	0.2244	0.2274	0.2307	0.2365	0.2392	0.2500
1/4	56	NS-2	0.1607	0.2500	0.2460	0.2384	0.2358	0.2281	0.2307	0.2338	0.2384	0.2410	0.2500
5/16	20	NS-2	0.4500	0.3125	0.3053	0.2800	0.2762	0.2512	0.2584	0.2672	0.2800	0.2838	0.3125
5/16	28	NS-2	0.3214	0.3125	0.3063	0.2893	0.2860	0.2687	0.2738	0.2794	0.2893	0.2926	0.3125
5/16	32	NEF-2	0.2812	0.3125	0.3071	0.2922	0.2889	0.2742	0.2787	0.2835	0.2922	0.2955	0.3125
5/16	36	NS-2	0.2500	0.3125	0.3075	0.2945	0.2915	0.2784	0.2824	0.2866	0.2945	0.2975	0.3125
5/16	40	NS-2	0.2250	0.3125	0.3077	0.2963	0.2934	0.2818	0.2854	0.2892	0.2963	0.2992	0.3125
5/16	48	NS-2	0.1875	0.3125	0.3081	0.2990	0.2963	0.2869	0.2899	0.2932	0.2990	0.3017	0.3125
3/8	18	NS-2	0.5000	0.3750	0.3668	0.3389	0.3347	0.3068	0.3149	0.3240	0.3389	0.3431	0.3750
3/8	20	NS-2	0.4500	0.3750	0.3678	0.3425	0.3384	0.3137	0.3209	0.3284	0.3425	0.3466	0.3750
3/8	28	NS-2	0.3214	0.3750	0.3688	0.3518	0.3483	0.3312	0.3363	0.3419	0.3518	0.3553	0.3750
3/8	32	NEF-2	0.2812	0.3750	0.3696	0.3547	0.3513	0.3367	0.3412	0.3460	0.3547	0.3581	0.3750
3/8	40	NS-2	0.2250	0.3750	0.3702	0.3588	0.3557	0.3443	0.3479	0.3517	0.3588	0.3619	0.3750
7/16	16	NS-2	0.5625	0.4375	0.4285	0.3969	0.3924	0.3608	0.3698	0.3795	0.3969	0.4014	0.4375
7/16	18	NS-2	0.5000	0.4375	0.4293	0.4014	0.3972	0.3693	0.3774	0.3852	0.4014	0.4056	0.4375
7/16	24	NS-2	0.3750	0.4375	0.4309	0.4104	0.4066	0.3864	0.3924	0.3988	0.4104	0.4142	0.4375
7/16	28	NEF-2	0.3214	0.4375	0.4313	0.4143	0.4107	0.3937	0.3988	0.4044	0.4143	0.4179	0.4375
7/16	32	NS-2	0.2812	0.4375	0.4321	0.4172	0.4138	0.3992	0.4037	0.4085	0.4172	0.4206	0.4375
1/2	12	N-2	0.7500	0.5000	0.4888	0.4459	0.4403	0.3978	0.4098	0.4225	0.4459	0.4515	0.5000
1/2	14	NS-2	0.6429	0.5000	0.4902	0.4536	0.4487	0.4124	0.4227	0.4336	0.4536	0.4585	0.5000
1/2	16	NS-2	0.5625	0.5000	0.4910	0.4594	0.4547	0.4233	0.4323	0.4407	0.4594	0.4641	0.5000
1/2	18	NS-2	0.5000	0.5000	0.4918	0.4639	0.4595	0.4318	0.4399	0.4475	0.4639	0.4683	0.5000
1/2	24	NS-2	0.3750	0.5000	0.4934	0.4729	0.4689	0.4489	0.4549	0.4613	0.4729	0.4769	0.5000
1/2	28	NEF-2	0.3214	0.5000	0.4938	0.4768	0.4731	0.4562	0.4613	0.4669	0.4768	0.4805	0.5000
1/2	32	NS-2	0.2812	0.5000	0.4946	0.4797	0.4761	0.4617	0.4662	0.4710	0.4797	0.4833	0.5000
9/16	12	N-2	0.7500	0.5625	0.5513	0.5084	0.5028	0.4603	0.4723	0.4850	0.5084	0.5140	0.5625
9/16	14	NS-2	0.6429	0.5625	0.5527	0.5161	0.5112	0.4749	0.4852	0.4949	0.5161	0.5210	0.5625
9/16	16	NS-2	0.5625	0.5625	0.5535	0.5219	0.5172	0.4858	0.4948	0.5029	0.5219	0.5266	0.5625
9/16	20	NS-2	0.4500	0.5625	0.5553	0.5300	0.5258	0.5012	0.5084	0.5156	0.5300	0.5342	0.5625
9/16	24	NEF-2	0.3750	0.5625	0.5559	0.5354	0.5314	0.5114	0.5174	0.5239	0.5354	0.5394	0.5625
9/16	28	NS-2	0.3214	0.5625	0.5563	0.5393	0.5356	0.5187	0.5238	0.5294	0.5393	0.5430	0.5625
9/16	32	NS-2	0.2812	0.5625	0.5571	0.5422	0.5386	0.5242	0.5287	0.5335	0.5422	0.5458	0.5625
5/8	12	N-2	0.7500	0.6250	0.6138	0.5709	0.5653	0.5228	0.5348	0.5438	0.5709	0.5765	0.6250
5/8	14	NS-2	0.6429	0.6250	0.6152	0.5786	0.5735	0.5374	0.5477	0.5562	0.5786	0.5837	0.6250
5/8	16	NS-2	0.5625	0.6250	0.6160	0.5844	0.5796	0.5483	0.5573	0.5654	0.5844	0.5892	0.6250
5/8	20	NS-2	0.4500	0.6250	0.6178	0.5925	0.5881	0.5637	0.5709	0.5781	0.5925	0.5969	0.6250
5/8	24	NEF-2	0.3750	0.6250	0.6184	0.5979	0.5938	0.5739	0.5799	0.5864	0.5979	0.6020	0.6250
5/8	28	NS-2	0.3214	0.6250	0.6188	0.6018	0.5979	0.5812	0.5863	0.5919	0.6018	0.6057	0.6250
5/8	32	NS-2	0.2812	0.6250	0.6196	0.6047	0.6010	0.5867	0.5912	0.5960	0.6047	0.6084	0.6250
11/16	12	N-2	0.7500	0.6875	0.6763	0.6334	0.6278	0.5853	0.5973	0.6063	0.6334	0.6390	0.6875
11/16	24	NEF-2	0.3750	0.6875	0.6809	0.6604	0.6563	0.6364	0.6424	0.6489	0.6604	0.6645	0.6875

[a] See Fig. 1.

TABLE 19b—*Class 2, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
3/4	12	N-2	0.7500	0.7500	0.7388	0.6959	0.6903	0.6478	0.6598	0.6688	0.6959	0.7015	0.7500
3/4	14	NS-2	0.6429	0.7500	0.7402	0.7036	0.6983	0.6624	0.6727	0.6812	0.7036	0.7089	0.7500
3/4	16	N-2	0.5625	0.7500	0.7410	0.7094	0.7049	0.6733	0.6823	0.6903	0.7094	0.7139	0.7500
3/4	18	NS-2	0.5000	0.7500	0.7418	0.7139	0.7091	0.6818	0.6899	0.6975	0.7139	0.7187	0.7500
3/4	20	NEF-2	0.4500	0.7500	0.7428	0.7175	0.7129	0.6887	0.6959	0.7031	0.7175	0.7221	0.7500
3/4	24	NS-2	0.3750	0.7500	0.7434	0.7229	0.7186	0.6989	0.7049	0.7113	0.7229	0.7272	0.7500
3/4	28	NS-2	0.3214	0.7500	0.7438	0.7268	0.7228	0.7062	0.7113	0.7169	0.7268	0.7308	0.7500
3/4	32	NS-2	0.2812	0.7500	0.7446	0.7297	0.7258	0.7117	0.7162	0.7210	0.7297	0.7336	0.7500
13/16	12	N-2	0.7500	0.8125	0.8013	0.7584	0.7528	0.7103	0.7223	0.7313	0.7584	0.7640	0.8125
13/16	16	N-2	0.5625	0.8125	0.8035	0.7719	0.7668	0.7358	0.7448	0.7528	0.7719	0.7770	0.8125
13/16	20	NEF-2	0.4500	0.8125	0.8053	0.7800	0.7754	0.7512	0.7584	0.7656	0.7800	0.7846	0.8125
7/8	10	NS-2	0.9000	0.8750	0.8622	0.8100	0.8039	0.7523	0.7667	0.7776	0.8100	0.8161	0.8750
7/8	12	N-2	0.7500	0.8750	0.8638	0.8209	0.8153	0.7728	0.7848	0.7938	0.8209	0.8265	0.8750
7/8	16	N-2	0.5625	0.8750	0.8660	0.8344	0.8293	0.7983	0.8073	0.8153	0.8344	0.8395	0.8750
7/8	18	NS-2	0.5000	0.8750	0.8668	0.8389	0.8341	0.8068	0.8149	0.8225	0.8389	0.8437	0.8750
7/8	20	NEF-2	0.4500	0.8750	0.8678	0.8425	0.8378	0.8137	0.8209	0.8281	0.8425	0.8472	0.8750
7/8	24	NS-2	0.3750	0.8750	0.8684	0.8479	0.8436	0.8239	0.8299	0.8363	0.8479	0.8522	0.8750
7/8	28	NS-2	0.3214	0.8750	0.8688	0.8518	0.8478	0.8312	0.8363	0.8419	0.8518	0.8558	0.8750
7/8	32	NS-2	0.2812	0.8750	0.8696	0.8547	0.8508	0.8367	0.8412	0.8460	0.8547	0.8586	0.8750
15/16	12	N-2	0.7500	0.9375	0.9263	0.8834	0.8778	0.8353	0.8473	0.8563	0.8834	0.8890	0.9375
15/16	16	N-2	0.5625	0.9375	0.9285	0.8969	0.8917	0.8608	0.8698	0.8778	0.8969	0.9021	0.9375
15/16	20	NEF-2	0.4500	0.9375	0.9303	0.9050	0.9003	0.8762	0.8834	0.8906	0.9050	0.9097	0.9375
1	10	NS-2	0.9000	1.0000	0.9872	0.9350	0.9286	0.8773	0.8917	0.9025	0.9350	0.9414	1.0000
1	12	N-2	0.7500	1.0000	0.9888	0.9459	0.9403	0.8978	0.9098	0.9188	0.9459	0.9515	1.0000
1	16	N-2	0.5625	1.0000	0.9910	0.9594	0.9542	0.9233	0.9323	0.9403	0.9594	0.9646	1.0000
1	18	NS-2	0.5000	1.0000	0.9918	0.9639	0.9589	0.9318	0.9399	0.9475	0.9639	0.9689	1.0000
1	20	NEF-2	0.4500	1.0000	0.9928	0.9675	0.9627	0.9387	0.9459	0.9531	0.9675	0.9723	1.0000
1	24	NS-2	0.3750	1.0000	0.9934	0.9729	0.9684	0.9489	0.9549	0.9613	0.9729	0.9774	1.0000
1	28	NS-2	0.3214	1.0000	0.9938	0.9768	0.9725	0.9562	0.9613	0.9669	0.9768	0.9811	1.0000
1	32	NS-2	0.2812	1.0000	0.9946	0.9797	0.9756	0.9617	0.9662	0.9710	0.9797	0.9838	1.0000
1 1/16	12	N-2	0.7500	1.0625	1.0513	1.0084	1.0028	0.9603	0.9723	0.9813	1.0084	1.0140	1.0625
1 1/16	16	N-2	0.5625	1.0625	1.0535	1.0219	1.0166	0.9858	0.9948	1.0028	1.0219	1.0272	1.0625
1 1/16	18	NEF-2	0.5000	1.0625	1.0543	1.0264	1.0213	0.9943	1.0024	1.0100	1.0264	1.0315	1.0625
1 1/8	8[b]	N-2	1.1250	1.1250	1.1098	1.0438	1.0368	0.9716	0.9897	1.0032	1.0438	1.0508	1.1250
1 1/8	10	NS-2	0.9000	1.1250	1.1122	1.0600	1.0536	1.0023	1.0167	1.0275	1.0600	1.0664	1.1250
1 1/8	12	N-2	0.7500	1.1250	1.1138	1.0709	1.0653	1.0228	1.0348	1.0438	1.0709	1.0765	1.1250
1 1/8	14	NS-2	0.6429	1.1250	1.1152	1.0786	1.0731	1.0374	1.0477	1.0562	1.0786	1.0841	1.1250
1 1/8	16	N-2	0.5625	1.1250	1.1160	1.0844	1.0790	1.0483	1.0573	1.0653	1.0844	1.0898	1.1250
1 1/8	18	NEF-2	0.5000	1.1250	1.1168	1.0889	1.0837	1.0568	1.0649	1.0725	1.0889	1.0941	1.1250
1 1/8	20	NS-2	0.4500	1.1250	1.1178	1.0925	1.0877	1.0637	1.0709	1.0781	1.0925	1.0973	1.1250
1 1/8	24	NS-2	0.3750	1.1250	1.1184	1.0979	1.0934	1.0739	1.0799	1.0863	1.0979	1.1024	1.1250
1 1/8	28	NS-2	0.3214	1.1250	1.1188	1.1018	1.0975	1.0812	1.0863	1.0919	1.1018	1.1061	1.1250
1 3/16	12	N-2	0.7500	1.1875	1.1763	1.1334	1.1278	1.0853	1.0973	1.1063	1.1334	1.1390	1.1875
1 3/16	16	N-2	0.5625	1.1875	1.1785	1.1469	1.1415	1.1108	1.1198	1.1278	1.1469	1.1523	1.1875
1 3/16	18	NEF-2	0.5000	1.1875	1.1793	1.1514	1.1462	1.1193	1.1274	1.1350	1.1514	1.1566	1.1875
1 1/4	8[b]	N-2	1.1250	1.2500	1.2348	1.1688	1.1615	1.0966	1.1147	1.1282	1.1688	1.1761	1.2500
1 1/4	10	NS-2	0.9000	1.2500	1.2372	1.1850	1.1784	1.1273	1.1417	1.1525	1.1850	1.1916	1.2500
1 1/4	12	N-2	0.7500	1.2500	1.2388	1.1959	1.1903	1.1478	1.1598	1.1688	1.1959	1.2015	1.2500
1 1/4	14	NS-2	0.6429	1.2500	1.2402	1.2036	1.1978	1.1624	1.1727	1.1812	1.2036	1.2094	1.2500
1 1/4	16	N-2	0.5625	1.2500	1.2410	1.2094	1.2039	1.1733	1.1823	1.1903	1.2094	1.2149	1.2500
1 1/4	18	NEF-2	0.5000	1.2500	1.2418	1.2139	1.2086	1.1818	1.1899	1.1975	1.2139	1.2192	1.2500
1 1/4	20	NS-2	0.4500	1.2500	1.2428	1.2175	1.2124	1.1887	1.1959	1.2031	1.2175	1.2226	1.2500
1 1/4	24	NS-2	0.3750	1.2500	1.2434	1.2229	1.2181	1.1989	1.2049	1.2113	1.2229	1.2277	1.2500
1 5/16	12	N-2	0.7500	1.3125	1.3013	1.2584	1.2528	1.2103	1.2223	1.2313	1.2584	1.2640	1.3125
1 5/16	16	N-2	0.5625	1.3125	1.3035	1.2719	1.2664	1.2358	1.2448	1.2528	1.2719	1.2774	1.3125
1 5/16	18	NEF-2	0.5000	1.3125	1.3043	1.2764	1.2711	1.2443	1.2524	1.2600	1.2764	1.2817	1.3125

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 19c—*Class 2, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
1⅜	8[b]	NS-2	1.1250	1.3750	1.3598	1.2938	1.2865	1.2216	1.2397	1.2532	1.2938	1.3011	1.3750
1⅜	10	NS-2	0.9000	1.3750	1.3622	1.3100	1.3034	1.2523	1.2667	1.2775	1.3100	1.3166	1.3750
1⅜	12	N-2	0.7500	1.3750	1.3638	1.3209	1.3153	1.2728	1.2848	1.2938	1.3209	1.3265	1.3750
1⅜	14	NS-2	0.6429	1.3750	1.3652	1.3286	1.3228	1.2874	1.2977	1.3062	1.3286	1.3344	1.3750
1⅜	16	N-2	0.5625	1.3750	1.3660	1.3344	1.3288	1.2983	1.3073	1.3153	1.3344	1.3400	1.3750
1⅜	18	NEF-2	0.5000	1.3750	1.3668	1.3389	1.3335	1.3068	1.3149	1.3225	1.3389	1.3443	1.3750
1⅜	20	NS-2	0.4500	1.3750	1.3678	1.3425	1.3374	1.3137	1.3209	1.3281	1.3425	1.3476	1.3750
1⅜	24	NS-2	0.3750	1.3750	1.3684	1.3479	1.3431	1.3239	1.3299	1.3363	1.3479	1.3527	1.3750
1⁷⁄₁₆	12	N-2	0.7500	1.4375	1.4263	1.3834	1.3778	1.3353	1.3473	1.3563	1.3834	1.3890	1.4375
1⁷⁄₁₆	16	N-2	0.5625	1.4375	1.4285	1.3969	1.3913	1.3608	1.3698	1.3778	1.3969	1.4025	1.4375
1⁷⁄₁₆	18	NEF-2	0.5000	1.4375	1.4293	1.4014	1.3960	1.3693	1.3774	1.3850	1.4014	1.4068	1.4375
1½	8[b]	NS-2	1.1250	1.5000	1.4848	1.4188	1.4113	1.3466	1.3647	1.3782	1.4188	1.4263	1.5000
1½	10	NS-2	0.9000	1.5000	1.4872	1.4350	1.4282	1.3773	1.3917	1.4025	1.4350	1.4418	1.5000
1½	12	N-2	0.7500	1.5000	1.4888	1.4459	1.4403	1.3978	1.4098	1.4188	1.4459	1.4515	1.5000
1½	14	NS-2	0.6429	1.5000	1.4902	1.4536	1.4476	1.4124	1.4227	1.4312	1.4536	1.4596	1.5000
1½	16	N-2	0.5625	1.5000	1.4910	1.4594	1.4537	1.4233	1.4323	1.4403	1.4594	1.4651	1.5000
1½	18	NEF-2	0.5000	1.5000	1.4918	1.4639	1.4584	1.4318	1.4399	1.4475	1.4639	1.4694	1.5000
1½	20	NS-2	0.4500	1.5000	1.4928	1.4675	1.4622	1.4387	1.4459	1.4531	1.4675	1.4728	1.5000
1½	24	NS-2	0.3750	1.5000	1.4934	1.4729	1.4679	1.4489	1.4549	1.4613	1.4729	1.4779	1.5000
1⁹⁄₁₆	16	N-2	0.5625	1.5625	1.5535	1.5219	1.5161	1.4858	1.4948	1.5028	1.5219	1.5277	1.5625
1⁹⁄₁₆	18	NEF-2	0.5000	1.5625	1.5543	1.5264	1.5209	1.4943	1.5024	1.5100	1.5264	1.5319	1.5625
1⅝	6	NS-2	1.5000	1.6250	1.6048	1.5167	1.5082	1.4205	1.4446	1.4626	1.5167	1.5252	1.6250
1⅝	7	NS-2	1.2857	1.6250	1.6080	1.5322	1.5243	1.4497	1.4704	1.4859	1.5322	1.5401	1.6250
1⅝	8[b]	NS-2	1.1250	1.6250	1.6098	1.5438	1.5363	1.4716	1.4897	1.5032	1.5438	1.5513	1.6250
1⅝	10	NS-2	0.9000	1.6250	1.6122	1.5600	1.5532	1.5023	1.5167	1.5275	1.5600	1.5668	1.6250
1⅝	12	N-2	0.7500	1.6250	1.6138	1.5709	1.5645	1.5228	1.5348	1.5438	1.5709	1.5773	1.6250
1⅝	14	NS-2	0.6429	1.6250	1.6152	1.5786	1.5726	1.5374	1.5477	1.5562	1.5786	1.5846	1.6250
1⅝	16	N-2	0.5625	1.6250	1.6160	1.5844	1.5786	1.5483	1.5573	1.5653	1.5844	1.5902	1.6250
1⅝	18	NEF-2	0.5000	1.6250	1.6168	1.5889	1.5833	1.5568	1.5649	1.5725	1.5889	1.5945	1.6250
1⅝	20	NS-2	0.4500	1.6250	1.6178	1.5925	1.5872	1.5637	1.5709	1.5781	1.5925	1.5978	1.6250
1⅝	24	NS-2	0.3750	1.6250	1.6184	1.5979	1.5929	1.5739	1.5799	1.5863	1.5979	1.6029	1.6250
1¹¹⁄₁₆	16	N-2	0.5625	1.6875	1.6785	1.6469	1.6411	1.6108	1.6198	1.6278	1.6469	1.6527	1.6875
1¹¹⁄₁₆	18	NEF-2	0.5000	1.6875	1.6793	1.6514	1.6458	1.6193	1.6274	1.6350	1.6514	1.6570	1.6875
1¾	6	NS-2	1.5000	1.7500	1.7298	1.6417	1.6330	1.5455	1.5696	1.5876	1.6417	1.6504	1.7500
1¾	7	NS-2	1.2857	1.7500	1.7330	1.6572	1.6491	1.5747	1.5954	1.6109	1.6572	1.6653	1.7500
1¾	8[b]	NS-2	1.1250	1.7500	1.7348	1.6688	1.6611	1.5966	1.6147	1.6282	1.6688	1.6765	1.7500
1¾	10	NS-2	0.9000	1.7500	1.7372	1.6850	1.6780	1.6273	1.6417	1.6525	1.6850	1.6920	1.7500
1¾	12	N-2	0.7500	1.7500	1.7388	1.6959	1.6894	1.6478	1.6598	1.6688	1.6959	1.7024	1.7500
1¾	14	NS-2	0.6429	1.7500	1.7402	1.7036	1.6974	1.6624	1.6727	1.6812	1.7036	1.7098	1.7500
1¾	16	{NEF-2 / N-2}	0.5625	1.7500	1.7410	1.7094	1.7035	1.6733	1.6823	1.6903	1.7094	1.7153	1.7500
1¾	18	NS-2	0.5000	1.7500	1.7418	1.7139	1.7082	1.6818	1.6899	1.6975	1.7139	1.7196	1.7500
1¾	20	NS-2	0.4500	1.7500	1.7428	1.7175	1.7120	1.6887	1.6959	1.7031	1.7175	1.7230	1.7500
1¹³⁄₁₆	16	N-2	0.5625	1.8125	1.8035	1.7719	1.7660	1.7358	1.7448	1.7528	1.7719	1.7778	1.8125
1⅞	6	NS-2	1.5000	1.8750	1.8548	1.7667	1.7580	1.6705	1.6946	1.7126	1.7667	1.7754	1.8750
1⅞	7	NS-2	1.2857	1.8750	1.8580	1.7822	1.7741	1.6997	1.7204	1.7359	1.7822	1.7903	1.8750
1⅞	8[b]	NS-2	1.1250	1.8750	1.8598	1.7938	1.7861	1.7216	1.7397	1.7532	1.7938	1.8015	1.8750
1⅞	10	NS-2	0.9000	1.8750	1.8622	1.8100	1.8030	1.7523	1.7667	1.7775	1.8100	1.8170	1.8750
1⅞	12	N-2	0.7500	1.8750	1.8638	1.8209	1.8143	1.7728	1.7848	1.7938	1.8209	1.8275	1.8750
1⅞	14	NS-2	0.6429	1.8750	1.8652	1.8286	1.8224	1.7874	1.7977	1.8062	1.8286	1.8348	1.8750
1⅞	16	N-2	0.5625	1.8750	1.8660	1.8344	1.8284	1.7983	1.8073	1.8153	1.8344	1.8404	1.8750
1⅞	18	NS-2	0.5000	1.8750	1.8668	1.8389	1.8332	1.8068	1.8149	1.8225	1.8389	1.8446	1.8750
1⅞	20	NS-2	0.4500	1.8750	1.8678	1.8425	1.8370	1.8137	1.8209	1.8281	1.8425	1.8480	1.8750
1¹⁵⁄₁₆	16	N-2	0.5625	1.9375	1.9285	1.8969	1.8909	1.8608	1.8698	1.8778	1.8969	1.9029	1.9375

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 19d—*Class 2, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
2	6	NS-2	1.5000	2.0000	1.9798	1.8917	1.8828	1.7955	1.8196	1.8376	1.8917	1.9006	2.0000
2	7	NS-2	1.2857	2.0000	1.9830	1.9072	1.8989	1.8247	1.8454	1.8609	1.9072	1.9155	2.0000
2	8[b]	NS-2	1.1250	2.0000	1.9848	1.9188	1.9109	1.8466	1.8647	1.8782	1.9188	1.9267	2.0000
2	10	NS-2	0.9000	2.0000	1.9872	1.9350	1.9278	1.8773	1.8917	1.9025	1.9350	1.9422	2.0000
2	12	N-2	0.7500	2.0000	1.9888	1.9459	1.9392	1.8978	1.9098	1.9188	1.9459	1.9526	2.0000
2	14	NS-2	0.6429	2.0000	1.9902	1.9536	1.9472	1.9124	1.9227	1.9312	1.9536	1.9600	2.0000
2	16	NEF-2 / N-2	0.5625	2.0000	1.9910	1.9594	1.9533	1.9233	1.9323	1.9403	1.9594	1.9655	2.0000
2	18	NS-2	0.5000	2.0000	1.9918	1.9639	1.9581	1.9318	1.9399	1.9475	1.9639	1.9697	2.0000
2	20	NS-2	0.4500	2.0000	1.9928	1.9675	1.9618	1.9387	1.9459	1.9531	1.9675	1.9732	2.0000
2 1/16	16	N-2	0.5625	2.0625	2.0535	2.0219	2.0158	1.9858	1.9948	2.0028	2.0219	2.0280	2.0625
2 1/8	12	N-2	0.7500	2.1250	2.1138	2.0709	2.0641	2.0228	2.0348	2.0438	2.0709	2.0777	2.1250
2 1/8	16	N-2	0.5625	2.1250	2.1160	2.0844	2.0782	2.0483	2.0573	2.0653	2.0844	2.0906	2.1250
2 3/16	16	N-2	0.5625	2.1875	2.1785	2.1469	2.1407	2.1108	2.1198	2.1278	2.1469	2.1531	2.1875
2 1/4	6	NS-2	1.5000	2.2500	2.2298	2.1417	2.1328	2.0455	2.0696	2.0876	2.1417	2.1506	2.2500
2 1/4	7	NS-2	1.2857	2.2500	2.2330	2.1572	2.1489	2.0747	2.0954	2.1109	2.1572	2.1655	2.2500
2 1/4	8[b]	NS-2	1.1250	2.2500	2.2348	2.1688	2.1609	2.0966	2.1147	2.1282	2.1688	2.1767	2.2500
2 1/4	10	NS-2	0.9000	2.2500	2.2372	2.1850	2.1778	2.1273	2.1417	2.1525	2.1850	2.1922	2.2500
2 1/4	12	N-2	0.7500	2.2500	2.2388	2.1959	2.1890	2.1478	2.1598	2.1688	2.1959	2.2028	2.2500
2 1/4	14	NS-2	0.6429	2.2500	2.2402	2.2036	2.1972	2.1624	2.1727	2.1812	2.2036	2.2100	2.2500
2 1/4	16	N-2	0.5625	2.2500	2.2410	2.2094	2.2032	2.1733	2.1823	2.1903	2.2094	2.2156	2.2500
2 1/4	18	NS-2	0.5000	2.2500	2.2418	2.2139	2.2081	2.1818	2.1899	2.1975	2.2139	2.2197	2.2500
2 1/4	20	NS-2	0.4500	2.2500	2.2428	2.2175	2.2118	2.1887	2.1959	2.2031	2.2175	2.2232	2.2500
2 5/16	16	N-2	0.5625	2.3125	2.3035	2.2719	2.2656	2.2358	2.2448	2.2528	2.2719	2.2782	2.3125
2 3/8	12	N-2	0.7500	2.3750	2.3638	2.3209	2.3139	2.2728	2.2848	2.2938	2.3209	2.3279	2.3750
2 3/8	16	N-2	0.5625	2.3750	2.3660	2.3344	2.3281	2.2983	2.3073	2.3153	2.3344	2.3407	2.3750
2 7/16	16	N-2	0.5625	2.4375	2.4285	2.3969	2.3905	2.3608	2.3698	2.3778	2.3969	2.4033	2.4375
2 1/2	6	NS-2	1.5000	2.5000	2.4798	2.3917	2.3825	2.2955	2.3196	2.3376	2.3917	2.4009	2.5000
2 1/2	7	NS-2	1.2857	2.5000	2.4830	2.4072	2.3985	2.3247	2.3454	2.3609	2.4072	2.4159	2.5000
2 1/2	8[b]	NS-2	1.1250	2.5000	2.4848	2.4188	2.4106	2.3466	2.3647	2.3782	2.4188	2.4270	2.5000
2 1/2	10	NS-2	0.9000	2.5000	2.4872	2.4350	2.4275	2.3773	2.3917	2.4025	2.4350	2.4425	2.5000
2 1/2	12	N-2	0.7500	2.5000	2.4888	2.4459	2.4388	2.3978	2.4098	2.4188	2.4459	2.4530	2.5000
2 1/2	14	NS-2	0.6429	2.5000	2.4902	2.4536	2.4469	2.4124	2.4227	2.4312	2.4536	2.4603	2.5000
2 1/2	16	N-2	0.5625	2.5000	2.4910	2.4594	2.4530	2.4233	2.4323	2.4403	2.4594	2.4658	2.5000
2 1/2	18	NS-2	0.5000	2.5000	2.4918	2.4639	2.4577	2.4318	2.4399	2.4475	2.4639	2.4701	2.5000
2 1/2	20	NS-2	0.4500	2.5000	2.4928	2.4675	2.4615	2.4387	2.4459	2.4531	2.4675	2.4735	2.5000
2 5/8	12	N-2	0.7500	2.6250	2.6138	2.5709	2.5638	2.5228	2.5348	2.5438	2.5709	2.5780	2.6250
2 5/8	16	N-2	0.5625	2.6250	2.6160	2.5844	2.5779	2.5483	2.5573	2.5653	2.5844	2.5909	2.6250
2 3/4	6	NS-2	1.5000	2.7500	2.7298	2.6417	2.6325	2.5455	2.5696	2.5876	2.6417	2.6509	2.7500
2 3/4	7	NS-2	1.2857	2.7500	2.7330	2.6572	2.6485	2.5747	2.5954	2.6109	2.6572	2.6659	2.7500
2 3/4	8[b]	NS-2	1.1250	2.7500	2.7348	2.6688	2.6606	2.5966	2.6147	2.6282	2.6688	2.6770	2.7500
2 3/4	10	NS-2	0.9000	2.7500	2.7372	2.6850	2.6775	2.6273	2.6417	2.6525	2.6850	2.6925	2.7500
2 3/4	12	N-2	0.7500	2.7500	2.7388	2.6959	2.6887	2.6478	2.6598	2.6688	2.6959	2.7031	2.7500
2 3/4	14	NS-2	0.6429	2.7500	2.7402	2.7036	2.6969	2.6624	2.6727	2.6812	2.7036	2.7103	2.7500
2 3/4	16	N-2	0.5625	2.7500	2.7410	2.7094	2.7028	2.6733	2.6823	2.6903	2.7094	2.7160	2.7500
2 3/4	18	NS-2	0.5000	2.7500	2.7418	2.7139	2.7077	2.6818	2.6899	2.6975	2.7139	2.7201	2.7500
2 7/8	12	N-2	0.7500	2.8750	2.8638	2.8209	2.8136	2.7728	2.7848	2.7938	2.8209	2.8282	2.8750
2 7/8	16	N-2	0.5625	2.8750	2.8660	2.8344	2.8278	2.7983	2.8073	2.8153	2.8344	2.8410	2.8750
3	6	NS-2	1.5000	3.0000	2.9798	2.8917	2.8822	2.7955	2.8196	2.8376	2.8917	2.9012	3.0000
3	7	NS-2	1.2857	3.0000	2.9830	2.9072	2.8982	2.8247	2.8454	2.8609	2.9072	2.9162	3.0000
3	8[b]	NS-2	1.1250	3.0000	2.9848	2.9188	2.9103	2.8466	2.8647	2.8782	2.9188	2.9273	2.0000
3	10	NS-2	0.9000	3.0000	2.9872	2.9350	2.9272	2.8773	2.8917	2.9025	2.9350	2.9428	3.0000
3	12	N-2	0.7500	3.0000	2.9888	2.9459	2.9385	2.8978	2.9098	2.9188	2.9459	2.9533	3.0000
3	14	NS-2	0.6429	3.0000	2.9902	2.9536	2.9466	2.9124	2.9227	2.9312	2.9536	2.9606	3.0000
3	16	N-2	0.5625	3.0000	2.9910	2.9594	2.9527	2.9233	2.9323	2.9403	2.9594	2.9661	3.0000
3	18	NS-2	0.5000	3.0000	2.9918	2.9639	2.9574	2.9318	2.9399	2.9475	2.9639	2.9704	3.0000

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 19e—*Class 2, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
3 1/8	12	N-2	0.7500	3.1250	3.1138	3.0709	3.0635	3.0228	3.0348	3.0438	3.0709	3.0783	3.1250
3 1/8	16	N-2	0.5625	3.1250	3.1160	3.0844	3.0776	3.0483	3.0573	3.0653	3.0844	3.0912	3.1250
3 1/4	6	NS-2	1.5000	3.2500	3.2298	3.1417	3.1322	3.0455	3.0696	3.0876	3.1417	3.1512	3.2500
3 1/4	7	NS-2	1.2857	3.2500	3.2330	3.1572	3.1482	3.0747	3.0954	3.1109	3.1572	3.1662	3.2500
3 1/4	8[b]	NS-2	1.1250	3.2500	3.2348	3.1688	3.1603	3.0966	3.1147	3.1282	3.1688	3.1773	3.2500
3 1/4	10	NS-2	0.9000	3.2500	3.2372	3.1850	3.1772	3.1273	3.1417	3.1525	3.1850	3.1928	3.2500
3 1/4	12	N-2	0.7500	3.2500	3.2388	3.1959	3.1884	3.1478	3.1598	3.1688	3.1959	3.2034	3.2500
3 1/4	14	NS-2	0.6429	3.2500	3.2402	3.2036	3.1966	3.1624	3.1727	3.1812	3.2036	3.2106	3.2500
3 1/4	16	N-2	0.5625	3.2500	3.2410	3.2094	3.2025	3.1733	3.1823	3.1903	3.2094	3.2163	3.2500
3 1/4	18	NS-2	0.5000	3.2500	3.2418	3.2139	3.2074	3.1818	3.1899	3.1975	3.2139	3.2204	3.2500
3 3/8	12	N-2	0.7500	3.3750	3.3638	3.3209	3.3133	3.2728	3.2848	3.2938	3.3209	3.3285	3.3750
3 3/8	16	N-2	0.5625	3.3750	3.3660	3.3344	3.3275	3.2983	3.3073	3.3153	3.3344	3.3413	3.3750
3 1/2	6	NS-2	1.5000	3.5000	3.4798	3.3917	3.3819	3.2955	3.3196	3.3376	3.3917	3.4015	3.5000
3 1/2	7	NS-2	1.2857	3.5000	3.4830	3.4072	3.3980	3.3247	3.3454	3.3609	3.4072	3.4164	3.5000
3 1/2	8[b]	NS-2	1.1250	3.5000	3.4848	3.4188	3.4100	3.3466	3.3647	3.3782	3.4188	3.4276	3.5000
3 1/2	10	NS-2	0.9000	3.5000	3.4872	3.4350	3.4269	3.3773	3.3917	3.4025	3.4350	3.4431	3.5000
3 1/2	12	N-2	0.7500	3.5000	3.4888	3.4459	3.4383	3.3978	3.4098	3.4188	3.4459	3.4535	3.5000
3 1/2	14	NS-2	0.6429	3.5000	3.4902	3.4536	3.4463	3.4124	3.4227	3.4312	3.4536	3.4609	3.5000
3 1/2	16	N-2	0.5625	3.5000	3.4910	3.4594	3.4524	3.4233	3.4323	3.4403	3.4594	3.4664	3.5000
3 1/2	18	NS-2	0.5000	3.5000	3.4918	3.4639	3.4571	3.4318	3.4399	3.4475	3.4639	3.4707	3.5000
3 5/8	12	N-2	0.7500	3.6250	3.6138	3.5709	3.5632	3.5228	3.5348	3.5438	3.5709	3.5786	3.6250
3 5/8	16	N-2	0.5625	3.6250	3.6160	3.5844	3.5773	3.5483	3.5573	3.5653	3.5844	3.5915	3.6250
3 3/4	6	NS-2	1.5000	3.7500	3.7298	3.6417	3.6319	3.5455	3.5696	3.5876	3.6417	3.6515	3.7500
3 3/4	7	NS-2	1.2857	3.7500	3.7330	3.6572	3.6480	3.5747	3.5954	3.6109	3.6572	3.6664	3.7500
3 3/4	8[b]	NS-2	1.1250	3.7500	3.7348	3.6688	3.6600	3.5966	3.6147	3.6282	3.6688	3.6776	3.7500
3 3/4	10	NS-2	0.9000	3.7500	3.7372	3.6850	3.6769	3.6273	3.6417	3.6525	3.6850	3.6931	3.7500
3 3/4	12	N-2	0.7500	3.7500	3.7388	3.6959	3.6881	3.6478	3.6598	3.6688	3.6959	3.7037	3.7500
3 3/4	14	NS-2	0.6429	3.7500	3.7402	3.7036	3.6963	3.6624	3.6727	3.6812	3.7036	3.7109	3.7500
3 3/4	16	N-2	0.5625	3.7500	3.7410	3.7094	3.7023	3.6733	3.6823	3.6903	3.7094	3.7165	3.7500
3 3/4	18	NS-2	0.5000	3.7500	3.7418	3.7139	3.7071	3.6818	3.6899	3.6975	3.7139	3.7207	3.7500
3 7/8	12	N-2	0.7500	3.8750	3.8638	3.8209	3.8131	3.7728	3.7848	3.7938	3.8209	3.8287	3.8750
3 7/8	16	N-2	0.5625	3.8750	3.8660	3.8344	3.8272	3.7983	3.8073	3.8153	3.8344	3.8416	3.8750
4	6	NS-2	1.5000	4.0000	3.9798	3.8917	3.8816	3.7955	3.8196	3.8376	3.8917	3.9018	4.0000
4	7	NS-2	1.2857	4.0000	3.9830	3.9072	3.8977	3.8247	3.8454	3.8609	3.9072	3.9167	4.0000
4	8[b]	NS-2	1.1250	4.0000	3.9848	3.9188	3.9098	3.8466	3.8647	3.8782	3.9188	3.9278	4.0000
4	10	NS-2	0.9000	4.0000	3.9872	3.9350	3.9266	3.8773	3.8917	3.9025	3.9350	3.9434	4.0000
4	12	N-2	0.7500	4.0000	3.9888	3.9459	3.9380	3.8978	3.9098	3.9188	3.9459	3.9538	4.0000
4	14	NS-2	0.6429	4.0000	3.9902	3.9536	3.9461	3.9124	3.9227	3.9312	3.9536	3.9611	4.0000
4	16	N-2	0.5625	4.0000	3.9910	3.9594	3.9522	3.9233	3.9323	3.9403	3.9594	3.9666	4.0000
4 1/4	4	NS-2	2.2500	4.2500	4.2220	4.0876	4.0756	3.9433	3.9794	4.0065	4.0876	4.0996	4.2500
4 1/4	6	NS-2	1.5000	4.2500	4.2298	4.1417	4.1316	4.0455	4.0696	4.0876	4.1417	4.1518	4.2500
4 1/4	7	NS-2	1.2857	4.2500	4.2330	4.1572	4.1477	4.0747	4.0954	4.1109	4.1572	4.1667	4.2500
4 1/4	8[b]	NS-2	1.1250	4.2500	4.2348	4.1688	4.1598	4.0966	4.1147	4.1282	4.1688	4.1778	4.2500
4 1/4	10	NS-2	0.9000	4.2500	4.2372	4.1850	4.1766	4.1273	4.1417	4.1525	4.1850	4.1934	4.2500
4 1/4	12	N-2	0.7500	4.2500	4.2388	4.1959	4.1879	4.1478	4.1598	4.1688	4.1959	4.2039	4.2500
4 1/4	14	NS-2	0.6429	4.2500	4.2402	4.2036	4.1961	4.1624	4.1727	4.1812	4.2036	4.2111	4.2500
4 1/4	16	N-2	0.5625	4.2500	4.2410	4.2094	4.2020	4.1733	4.1823	4.1903	4.2094	4.2168	4.2500
4 1/2	4	NS-2	2.2500	4.5000	4.4720	4.3376	4.3256	4.1933	4.2294	4.2565	4.3376	4.3496	4.5000
4 1/2	6	NS-2	1.5000	4.5000	4.4798	4.3917	4.3816	4.2955	4.3196	4.3376	4.3917	4.4018	4.5000
4 1/2	7	NS-2	1.2857	4.5000	4.4830	4.4072	4.3977	4.3247	4.3454	4.3609	4.4072	4.4167	4.5000
4 1/2	8[b]	NS-2	1.1250	4.5000	4.4848	4.4188	4.4098	4.3466	4.3647	4.3782	4.4188	4.4278	4.5000
4 1/2	10	NS-2	0.9000	4.5000	4.4872	4.4350	4.4266	4.3773	4.3917	4.4025	4.4350	4.4434	4.5000
4 1/2	12	N-2	0.7500	4.5000	4.4888	4.4459	4.4378	4.3978	4.4098	4.4188	4.4459	4.4540	4.5000
4 1/2	14	NS-2	0.6429	4.5000	4.4902	4.4536	4.4461	4.4124	4.4227	4.4312	4.4536	4.4611	4.5000
4 1/2	16	N-2	0.5625	4.5000	4.4910	4.4594	4.4519	4.4233	4.4323	4.4403	4.4594	4.4669	4.5000

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 19f—*Class 2, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
4¾	4	NS-2	2.2500	4.7500	4.7220	4.5876	4.5751	4.4433	4.4794	4.5065	4.5876	4.6001	4.7500
4¾	6	NS-2	1.5000	4.7500	4.7298	4.6417	4.6312	4.5455	4.5696	4.5876	4.6417	4.6522	4.7500
4¾	7	NS-2	1.2857	4.7500	4.7330	4.6572	4.6472	4.5747	4.5954	4.6109	4.6572	4.6672	4.7500
4¾	8[b]	NS-2	1.1250	4.7500	4.7348	4.6688	4.6593	4.5966	4.6147	4.6282	4.6688	4.6783	4.7500
4¾	10	NS-2	0.9000	4.7500	4.7372	4.6850	4.6762	4.6273	4.6417	4.6525	4.6850	4.6938	4.7500
4¾	12	N-2	0.7500	4.7500	4.7388	4.6959	4.6876	4.6478	4.6598	4.6688	4.6959	4.7042	4.7500
4¾	14	NS-2	0.6429	4.7500	4.7402	4.7036	4.6956	4.6624	4.6727	4.6812	4.7026	4.7106	4.7500
4¾	16	N-2	0.5625	4.7500	4.7410	4.7094	4.7018	4.6733	4.6823	4.6903	4.7094	4.7170	4.7500
5	4	NS-2	2.2500	5.0000	4.9720	4.8376	4.8251	4.6933	4.7294	4.7565	4.8376	4.8501	5.0000
5	6	NS-2	1.5000	5.0000	4.9798	4.8917	4.8812	4.7955	4.8196	4.8376	4.8917	4.9022	5.0000
5	7	NS-2	1.2857	5.0000	4.9830	4.9072	4.8972	4.8247	4.8454	4.8609	4.9072	4.9172	5.0000
5	8[b]	NS-2	1.1250	5.0000	4.9848	4.9188	4.9093	4.8466	4.8647	4.8782	4.9188	4.9283	5.0000
5	10	NS-2	0.9000	5.0000	4.9872	4.9350	4.9262	4.8773	4.8917	4.9025	4.9350	4.9438	5.0000
5	12	N-2	0.7500	5.0000	4.9888	4.9459	4.9375	4.8978	4.9098	4.9188	4.9459	4.9543	5.0000
5	14	NS-2	0.6429	5.0000	4.9902	4.9536	4.9456	4.9124	4.9227	4.9312	4.9536	4.9616	5.0000
5	16	N-2	0.5625	5.0000	4.9910	4.9594	4.9517	4.9233	4.9323	4.9403	4.9594	4.9671	5.0000
5¼	4	NS-2	2.2500	5.2500	5.2220	5.0876	5.0751	4.9433	4.9794	5.0065	5.0876	5.1001	5.2500
5¼	6	NS-2	1.5000	5.2500	5.2298	5.1417	5.1312	5.0455	5.0696	5.0876	5.1417	5.1522	5.2500
5¼	7	NS-2	1.2857	5.2500	5.2330	5.1572	5.1472	5.0747	5.0954	5.1109	5.1572	5.1672	5.2500
5¼	8[b]	NS-2	1.1250	5.2500	5.2348	5.1688	5.1593	5.0966	5.1147	5.1282	5.1688	5.1783	5.2500
5¼	10	NS-2	0.9000	5.2500	5.2372	5.1850	5.1762	5.1273	5.1417	5.1525	5.1850	5.1938	5.2500
5¼	12	N-2	0.7500	5.2500	5.2388	5.1959	5.1874	5.1478	5.1598	5.1688	5.1959	5.2044	5.2500
5¼	14	NS-2	0.6429	5.2500	5.2402	5.2036	5.1956	5.1624	5.1727	5.1812	5.2036	5.2116	5.2500
5¼	16	N-2	0.5625	5.2500	5.2410	5.2094	5.2016	5.1733	5.1823	5.1903	5.2094	5.2172	5.2500
5½	4	NS-2	2.2500	5.5000	5.4720	5.3376	5.3251	5.1933	5.2294	5.2565	5.3376	5.3501	5.5000
5½	6	NS-2	1.5000	5.5000	5.4798	5.3917	5.3812	5.2955	5.3196	5.3376	5.3917	5.4022	5.5000
5½	7	NS-2	1.2857	5.5000	5.4830	5.4072	5.3972	5.3247	5.3454	5.3609	5.4072	5.4172	5.5000
5½	8[b]	NS-2	1.1250	5.5000	5.4848	5.4188	5.4093	5.3466	5.3647	5.3782	5.4188	5.4283	5.5000
5½	10	NS-2	0.9000	5.5000	5.4872	5.4350	5.4262	5.3773	5.3917	5.4025	5.4350	5.4438	5.5000
5½	12	N-2	0.7500	5.5000	5.4888	5.4459	5.4373	5.3978	5.4098	5.4188	5.4459	5.4545	5.5000
5½	14	NS-2	0.6429	5.5000	5.4902	5.4536	5.4456	5.4124	5.4227	5.4312	5.4536	5.4616	5.5000
5½	16	N-2	0.5625	5.5000	5.4910	5.4594	5.4515	5.4233	5.4323	5.4403	5.4594	5.4673	5.5000
5¾	4	NS-2	2.2500	5.7500	5.7220	5.5876	5.5747	5.4433	5.4794	5.5065	5.5876	5.6005	5.7500
5¾	6	NS-2	1.5000	5.7500	5.7298	5.6417	5.6307	5.5455	5.5696	5.5876	5.6417	5.6527	5.7500
5¾	7	NS-2	1.2857	5.7500	5.7330	5.6572	5.6468	5.5747	5.5954	5.6109	5.6572	5.6676	5.7500
5¾	8[b]	NS-2	1.1250	5.7500	5.7348	5.6688	5.6589	5.5966	5.6147	5.6282	5.6688	5.6787	5.7500
5¾	10	NS-2	0.9000	5.7500	5.7372	5.6850	5.6757	5.6273	5.6417	5.6525	5.6850	5.6943	5.7500
5¾	12	N-2	0.7500	5.7500	5.7388	5.6959	5.6872	5.6478	5.6598	5.6688	5.6959	5.7046	5.7500
5¾	14	NS-2	0.6429	5.7500	5.7402	5.7036	5.6952	5.6624	5.6727	5.6812	5.7036	5.7120	5.7500
5¾	16	N-2	0.5625	5.7500	5.7410	5.7094	5.7014	5.6733	5.6823	5.6903	5.7094	5.7174	5.7500
6	4	NS-2	2.2500	6.0000	5.9720	5.8376	5.8247	5.6933	5.7294	5.7565	5.8376	5.8505	6.0000
6	6	NS-2	1.5000	6.0000	5.9798	5.8917	5.8807	5.7955	5.8196	5.8376	5.8917	5.9027	6.0000
6	7	NS-2	1.2857	6.0000	5.9830	5.9072	5.8968	5.8247	5.8454	5.8609	5.9072	5.9176	6.0000
6	8[b]	NS-2	1.1250	6.0000	5.9848	5.9188	5.9089	5.8466	5.8647	5.8782	5.9188	5.9287	6.0000
6	10	NS-2	0.9000	6.0000	5.9872	5.9350	5.9257	5.8773	5.8917	5.9025	5.9350	5.9443	6.0000
6	12	N-2	0.7500	6.0000	5.9888	5.9459	5.9371	5.8978	5.9098	5.9188	5.9459	5.9547	6.0000
6	14	NS-2	0.6429	6.0000	5.9902	5.9536	5.9452	5.9124	5.9227	5.9312	5.9536	5.9620	6.0000
6	16	N-2	0.5625	6.0000	5.9910	5.9594	5.9513	5.9233	5.9323	5.9403	5.9594	5.9675	6.0000

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 20a—*Class 3, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
10 (0.190)	28	NS-3	0.3214	0.1900	0.1838	0.1668	0.1646	0.1462	0.1513	0.1596	0.1668	0.1690	0.1900
10 (0.190)	36	NS-3	0.2500	0.1900	0.1850	0.1720	0.1700	0.1559	0.1599	0.1646	0.1720	0.1740	0.1900
10 (0.190)	40	NS-3	0.2250	0.1900	0.1852	0.1738	0.1719	0.1593	0.1629	0.1668	0.1738	0.1757	0.1900
10 (0.190)	48	NS-3	0.1875	0.1900	0.1856	0.1765	0.1747	0.1644	0.1674	0.1707	0.1765	0.1783	0.1900
10 (0.190)	56	NS-3	0.1607	0.1900	0.1860	0.1784	0.1767	0.1681	0.1707	0.1738	0.1784	0.1801	0.1900
12 (0.216)	32	NEF-3	0.2812	0.2160	0.2106	0.1957	0.1935	0.1777	0.1822	0.1875	0.1957	0.1979	0.2160
12 (0.216)	36	NS-3	0.2500	0.2160	0.2110	0.1980	0.1960	0.1819	0.1859	0.1901	0.1980	0.2000	0.2160
12 (0.216)	40	NS-3	0.2250	0.2160	0.2112	0.1998	0.1979	0.1853	0.1889	0.1927	0.1998	0.2017	0.2160
12 (0.216)	48	NS-3	0.1875	0.2160	0.2116	0.2025	0.2007	0.1904	0.1934	0.1967	0.2025	0.2043	0.2160
12 (0.216)	56	NS-3	0.1607	0.2160	0.2120	0.2044	0.2027	0.1941	0.1967	0.1998	0.2044	0.2061	0.2160
1/4	24	NS-3	0.3750	0.2500	0.2434	0.2229	0.2204	0.1989	0.2049	0.2126	0.2229	0.2254	0.2500
1/4	32	NEF-3	0.2812	0.2500	0.2446	0.2297	0.2275	0.2117	0.2162	0.2210	0.2297	0.2319	0.2500
1/4	36	NS-3	0.2500	0.2500	0.2450	0.2320	0.2299	0.2159	0.2199	0.2241	0.2320	0.2341	0.2500
1/4	40	NS-3	0.2250	0.2500	0.2452	0.2338	0.2318	0.2193	0.2229	0.2267	0.2338	0.2358	0.2500
1/4	48	NS-3	0.1875	0.2500	0.2456	0.2365	0.2346	0.2244	0.2274	0.2307	0.2365	0.2384	0.2500
1/4	56	NS-3	0.1607	0.2500	0.2460	0.2384	0.2366	0.2281	0.2307	0.2338	0.2384	0.2402	0.2500
5/16	20	NS-3	0.4500	0.3125	0.3053	0.2800	0.2773	0.2512	0.2584	0.2672	0.2800	0.2827	0.3125
5/16	28	NS-3	0.3214	0.3125	0.3063	0.2893	0.2870	0.2687	0.2738	0.2794	0.2893	0.2916	0.3125
5/16	32	NEF-3	0.2812	0.3125	0.3071	0.2922	0.2899	0.2742	0.2787	0.2835	0.2922	0.2945	0.3125
5/16	36	NS-3	0.2500	0.3125	0.3075	0.2945	0.2924	0.2784	0.2824	0.2866	0.2945	0.2966	0.3125
5/16	40	NS-3	0.2250	0.3125	0.3077	0.2963	0.2943	0.2818	0.2854	0.2892	0.2963	0.2983	0.3125
5/16	48	NS-2	0.1875	0.3125	0.3081	0.2990	0.2971	0.2869	0.2899	0.2932	0.2990	0.3009	0.3125
3/8	18	NS-3	0.5000	0.3750	0.3668	0.3389	0.3359	0.3068	0.3149	0.3240	0.3389	0.3419	0.3750
3/8	20	NS-3	0.4500	0.3750	0.3678	0.3425	0.3397	0.3137	0.3209	0.3284	0.3425	0.3453	0.3750
3/8	28	NS-3	0.3214	0.3750	0.3688	0.3518	0.3493	0.3312	0.3363	0.3419	0.3518	0.3543	0.3750
3/8	32	NEF-3	0.2812	0.3750	0.3696	0.3547	0.3523	0.3367	0.3412	0.3460	0.3547	0.3571	0.3750
3/8	40	NS-3	0.2250	0.3750	0.3702	0.3588	0.3566	0.3443	0.3479	0.3517	0.3588	0.3610	0.3750
7/16	16	NS-3	0.5625	0.4375	0.4285	0.3669	0.3938	0.3608	0.3698	0.3795	0.3969	0.4000	0.4375
7/16	18	NS-3	0.5000	0.4375	0.4293	0.4014	0.3984	0.3693	0.3774	0.3852	0.4014	0.4045	0.4375
7/16	24	NS-3	0.3750	0.4375	0.4309	0.4104	0.4078	0.3864	0.3924	0.3988	0.4104	0.4130	0.4375
7/16	28	NEF-3	0.3214	0.4375	0.4313	0.4143	0.4118	0.3937	0.3988	0.4044	0.4143	0.4168	0.4375
7/16	32	NS-3	0.2812	0.4375	0.4321	0.4172	0.4148	0.3992	0.4037	0.4085	0.4172	0.4196	0.4375
1/2	12	N-3	0.7500	0.5000	0.4888	0.4459	0.4419	0.3978	0.4098	0.4225	0.4459	0.4499	0.5000
1/2	14	NS-3	0.6429	0.5000	0.4902	0.4536	0.4501	0.4124	0.4227	0.4336	0.4536	0.4571	0.5000
1/2	16	NS-3	0.5625	0.5000	0.4910	0.4594	0.4561	0.4233	0.4323	0.4407	0.4594	0.4627	0.5000
1/2	18	NS-3	0.5000	0.5000	0.4918	0.4639	0.4608	0.4318	0.4399	0.4475	0.4639	0.4670	0.5000
1/2	24	NS-3	0.3750	0.5000	0.4934	0.4729	0.4701	0.4489	0.4549	0.4613	0.4729	0.4757	0.5000
1/2	28	NEF-3	0.3214	0.5000	0.4938	0.4768	0.4742	0.4562	0.4613	0.4669	0.4768	0.4794	0.5000
1/2	32	NS-3	0.2812	0.5000	0.4946	0.4797	0.4772	0.4617	0.4662	0.4710	0.4797	0.4822	0.5000
9/16	12	N-3	0.7500	0.5625	0.5513	0.5084	0.5044	0.4603	0.4723	0.4850	0.5084	0.5124	0.5625
9/16	14	NS-3	0.6429	0.5625	0.5527	0.5161	0.5126	0.4749	0.4852	0.4949	0.5161	0.5196	0.5625
9/16	16	NS-3	0.5625	0.5625	0.5535	0.5219	0.5186	0.4858	0.4948	0.5029	0.5219	0.5252	0.5625
9/16	20	NS-3	0.4500	0.5625	0.5553	0.5300	0.5270	0.5012	0.5084	0.5156	0.5300	0.5330	0.5625
9/16	24	NEF-3	0.3750	0.5625	0.5559	0.5354	0.5326	0.5114	0.5174	0.5239	0.5354	0.5382	0.5625
9/16	28	NS-3	0.3214	0.5625	0.5563	0.5393	0.5367	0.5187	0.5238	0.5294	0.5393	0.5419	0.5625
9/16	32	NS-3	0.2812	0.5625	0.5571	0.5422	0.5397	0.5242	0.5287	0.5335	0.5422	0.5447	0.5625
5/8	12	N-3	0.7500	0.6250	0.6138	0.5709	0.5669	0.5228	0.5348	0.5438	0.5709	0.5749	0.6250
5/8	14	NS-3	0.6429	0.6250	0.6152	0.5786	0.5750	0.5374	0.5477	0.5562	0.5786	0.5822	0.6250
5/8	16	NS-3	0.5625	0.6250	0.6160	0.5844	0.5810	0.5483	0.5573	0.5654	0.5844	0.5878	0.6250
5/8	20	NS-3	0.4500	0.6250	0.6178	0.5925	0.5894	0.5637	0.5709	0.5781	0.5925	0.5956	0.6250
5/8	24	NEF-3	0.3750	0.6250	0.6184	0.5979	0.5950	0.5739	0.5799	0.5864	0.5979	0.6008	0.6250
5/8	28	NS-3	0.3214	0.6250	0.6188	0.6018	0.5991	0.5812	0.5863	0.5919	0.6018	0.6045	0.6250
5/8	32	NS-3	0.2812	0.6250	0.6196	0.6047	0.6021	0.5867	0.5912	0.5960	0.6047	0.6073	0.6250
11/16	12	N-3	0.7500	0.6875	0.6763	0.6334	0.6294	0.5853	0.5973	0.6063	0.6334	0.6374	0.6875
11/16	24	NEF-3	0.3750	0.6875	0.6809	0.6604	0.6575	0.6364	0.6424	0.6489	0.6604	0.6633	0.6875

[a] See Fig. 1.

TABLE 20b—*Class 3, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION				EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol	L_e, 9 × PITCH	Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
3/4	12	N-3	0.7500	0.7500	0.7388	0.6959	0.6919	0.6478	0.6598	0.6688	0.6959	0.6999	0.7500
3/4	14	NS-3	0.6429	0.7500	0.7402	0.7036	0.6999	0.6624	0.6727	0.6812	0.7036	0.7073	0.7500
3/4	16	N-3	0.5625	0.7500	0.7410	0.7094	0.7062	0.6733	0.6823	0.6903	0.7094	0.7126	0.7500
3/4	18	NS-3	0.5000	0.7500	0.7418	0.7139	0.7106	0.6818	0.6899	0.6975	0.7139	0.7172	0.7500
3/4	20	NEF-3	0.4500	0.7500	0.7428	0.7175	0.7143	0.6887	0.6959	0.7031	0.7175	0.7207	0.7500
3/4	24	NS-3	0.3750	0.7500	0.7434	0.7229	0.7199	0.6989	0.7049	0.7113	0.7229	0.7259	0.7500
3/4	28	NS-3	0.3214	0.7500	0.7438	0.7268	0.7240	0.7062	0.7113	0.7169	0.7268	0.7296	0.7500
3/4	32	NS-3	0.2812	0.7500	0.7446	0.7297	0.7270	0.7117	0.7162	0.7210	0.7297	0.7324	0.7500
13/16	12	N-3	0.7500	0.8125	0.8013	0.7584	0.7544	0.7103	0.7223	0.7313	0.7584	0.7624	0.8125
13/16	16	N-3	0.5625	0.8125	0.8035	0.7719	0.7684	0.7358	0.7448	0.7528	0.7719	0.7754	0.8125
13/16	20	NEF-3	0.4500	0.8125	0.8053	0.7800	0.7768	0.7512	0.7584	0.7656	0.7800	0.7832	0.8125
7/8	10	NS-3	0.9000	0.8750	0.8622	0.8100	0.8057	0.7523	0.7667	0.7776	0.8100	0.8143	0.8750
7/8	12	N-3	0.7500	0.8750	0.8638	0.8209	0.8169	0.7728	0.7848	0.7938	0.8209	0.8249	0.8750
7/8	16	N-3	0.5625	0.8750	0.8660	0.8344	0.8308	0.7983	0.8073	0.8153	0.8344	0.8380	0.8750
7/8	18	NS-3	0.5000	0.8750	0.8668	0.8389	0.8356	0.8068	0.8149	0.8225	0.8389	0.8422	0.8750
7/8	20	NEF-3	0.4500	0.8750	0.8678	0.8425	0.8392	0.8137	0.8209	0.8281	0.8425	0.8458	0.8750
7/8	24	NS-3	0.3750	0.8750	0.8684	0.8479	0.8449	0.8239	0.8299	0.8363	0.8479	0.8509	0.8750
7/8	28	NS-3	0.3214	0.8750	0.8688	0.8518	0.8490	0.8312	0.8363	0.8419	0.8518	0.8546	0.8750
7/8	32	NS-3	0.2812	0.8750	0.8696	0.8547	0.8520	0.8367	0.8412	0.8460	0.8547	0.8574	0.8750
15/16	12	N-3	0.7500	0.9375	0.9263	0.8834	0.8794	0.8353	0.8473	0.8563	0.8834	0.8874	0.9375
15/16	16	N-3	0.5625	0.9375	0.9285	0.8969	0.8933	0.8608	0.8698	0.8778	0.8969	0.9005	0.9375
15/16	20	NEF-3	0.4500	0.9375	0.9303	0.9050	0.9017	0.8762	0.8834	0.8906	0.9050	0.9083	0.9375
1	10	NS-3	0.9000	1.0000	0.9872	0.9350	0.9305	0.8773	0.8917	0.9025	0.9350	0.9395	1.0000
1	12	N-3	0.7500	1.0000	0.9888	0.9459	0.9419	0.8978	0.9098	0.9188	0.9459	0.9499	1.0000
1	16	N-3	0.5625	1.0000	0.9910	0.9594	0.9557	0.9233	0.9323	0.9403	0.9594	0.9631	1.0000
1	18	NS-3	0.5000	1.0000	0.9918	0.9639	0.9604	0.9318	0.9399	0.9475	0.9639	0.9674	1.0000
1	20	NEF-3	0.4500	1.0000	0.9928	0.9675	0.9641	0.9387	0.9459	0.9531	0.9675	0.9709	1.0000
1	24	NS-3	0.3750	1.0000	0.9934	0.9729	0.9697	0.9489	0.9549	0.9613	0.9729	0.9761	1.0000
1	28	NS-3	0.3214	1.0000	0.9938	0.9768	0.9738	0.9562	0.9613	0.9669	0.9768	0.9798	1.0000
1	32	NS-3	0.2812	1.0000	0.9946	0.9797	0.9768	0.9617	0.9662	0.9710	0.9797	0.9826	1.0000
1 1/16	12	N-3	0.7500	1.0625	1.0513	1.0084	1.0044	0.9603	0.9723	0.9813	1.0084	1.0124	1.0625
1 1/16	16	N-3	0.5625	1.0625	1.0535	1.0219	1.0182	0.9858	0.9948	1.0028	1.0219	1.0256	1.0625
1 1/16	18	NEF-3	0.5000	1.0625	1.0543	1.0264	1.0228	0.9943	1.0024	1.0100	1.0264	1.0300	1.0625
1 1/8	8[b]	NS-3	1.1250	1.1250	1.1098	1.0438	1.0389	0.9716	0.9897	1.0032	1.0438	1.0487	1.1250
1 1/8	10	NS-3	0.9000	1.1250	1.1122	1.0600	1.0555	1.0023	1.0167	1.0275	1.0600	1.0645	1.1250
1 1/8	12	N-3	0.7500	1.1250	1.1138	1.0709	1.0669	1.0228	1.0348	1.0438	1.0709	1.0749	1.1250
1 1/8	14	NS-3	0.6429	1.1250	1.1152	1.0786	1.0747	1.0374	1.0477	1.0562	1.0786	1.0825	1.1250
1 1/8	16	N-3	0.5625	1.1250	1.1160	1.0844	1.0806	1.0483	1.0573	1.0653	1.0844	1.0882	1.1250
1 1/8	18	NEF-3	0.5000	1.1250	1.1168	1.0889	1.0853	1.0568	1.0649	1.0725	1.0889	1.0925	1.1250
1 1/8	20	NS-3	0.4500	1.1250	1.1178	1.0925	1.0891	1.0637	1.0709	1.0781	1.0925	1.0959	1.1250
1 1/8	24	NS-3	0.3750	1.1250	1.1184	1.0979	1.0947	1.0739	1.0799	1.0863	1.0979	1.1011	1.1250
1 1/8	28	NS-3	0.3214	1.1250	1.1188	1.1018	1.0988	1.0812	1.0863	1.0919	1.1018	1.1048	1.1250
1 3/16	12	N-3	0.7500	1.1875	1.1763	1.1334	1.1294	1.0853	1.0973	1.1063	1.1334	1.1374	1.1875
1 3/16	16	N-3	0.5625	1.1875	1.1785	1.1469	1.1431	1.1108	1.1198	1.1278	1.1469	1.1507	1.1875
1 3/16	18	NEF-3	0.5000	1.1875	1.1793	1.1514	1.1478	1.1193	1.1274	1.1350	1.1514	1.1550	1.1875
1 1/4	8[b]	NS-3	1.1250	1.2500	1.2348	1.1688	1.1637	1.0966	1.1147	1.1282	1.1688	1.1739	1.2500
1 1/4	10	NS-3	0.9000	1.2500	1.2372	1.1850	1.1804	1.1273	1.1417	1.1525	1.1850	1.1896	1.2500
1 1/4	12	N-3	0.7500	1.2500	1.2388	1.1959	1.1919	1.1478	1.1598	1.1688	1.1959	1.1999	1.2500
1 1/4	14	NS-3	0.6429	1.2500	1.2402	1.2036	1.1996	1.1624	1.1727	1.1812	1.2036	1.2076	1.2500
1 1/4	16	N-3	0.5625	1.2500	1.2410	1.2094	1.2056	1.1733	1.1823	1.1903	1.2094	1.2132	1.2500
1 1/4	18	NEF-3	0.5000	1.2500	1.2418	1.2139	1.2102	1.1818	1.1899	1.1975	1.2139	1.2176	1.2500
1 1/4	20	NS-3	0.4500	1.2500	1.2428	1.2175	1.2140	1.1887	1.1959	1.2031	1.2175	1.2210	1.2500
1 1/4	24	NS-3	0.3750	1.2500	1.2434	1.2229	1.2196	1.1989	1.2049	1.2113	1.2229	1.2262	1.2500
1 5/16	12	N-3	0.7500	1.3125	1.3013	1.2584	1.2544	1.2103	1.2223	1.2313	1.2584	1.2624	1.3125
1 5/16	16	N-3	0.5625	1.3125	1.3035	1.2719	1.2680	1.2358	1.2448	1.2528	1.2719	1.2758	1.3125
1 5/16	18	NEF-3	0.5000	1.3125	1.3043	1.2764	1.2727	1.2443	1.2524	1.2600	1.2764	1.2801	1.3125

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 20c—*Class 3, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
1 3/8	8[b]	NS-3	1.1250	1.3750	1.3598	1.2938	1.2887	1.2216	1.2397	1.2532	1.2938	1.2989	1.3750
1 3/8	10	NS-3	0.9000	1.3750	1.3622	1.3100	1.3054	1.2523	1.2667	1.2775	1.3100	1.3146	1.3750
1 3/8	12	N-3	0.7500	1.3750	1.3638	1.3209	1.3169	1.2728	1.2848	1.2938	1.3209	1.3249	1.3750
1 3/8	14	NS-3	0.6429	1.3750	1.3652	1.3286	1.3246	1.2874	1.2977	1.3062	1.3286	1.3326	1.3750
1 3/8	16	N-3	0.5625	1.3750	1.3660	1.3344	1.3305	1.2983	1.3073	1.3153	1.3344	1.3383	1.3750
1 3/8	18	NEF-3	0.5000	1.3750	1.3668	1.3389	1.3351	1.3068	1.3149	1.3225	1.3389	1.3427	1.3750
1 3/8	20	NS-3	0.4500	1.3750	1.3678	1.3425	1.3390	1.3137	1.3209	1.3281	1.3425	1.3460	1.3750
1 3/8	24	NS-3	0.3750	1.3750	1.3684	1.3479	1.3446	1.3239	1.3299	1.3363	1.3479	1.3512	1.3750
1 7/16	12	N-3	0.7500	1.4375	1.4263	1.3834	1.3794	1.3353	1.3473	1.3563	1.3834	1.3874	1.4375
1 7/16	16	N-3	0.5625	1.4375	1.4285	1.3969	1.3929	1.3608	1.3698	1.3778	1.3969	1.4009	1.4375
1 7/16	18	NEF-3	0.5000	1.4375	1.4293	1.4014	1.3976	1.3693	1.3774	1.3850	1.4014	1.4052	1.4375
1 1/2	8[b]	NS-3	1.1250	1.5000	1.4848	1.4188	1.4136	1.3466	1.3647	1.3782	1.4188	1.4240	1.5000
1 1/2	10	NS-3	0.9000	1.5000	1.4872	1.4350	1.4302	1.3773	1.3917	1.4025	1.4350	1.4398	1.5000
1 1/2	12	N-3	0.7500	1.5000	1.4888	1.4459	1.4419	1.3978	1.4098	1.4188	1.4459	1.4499	1.5000
1 1/2	14	NS-3	0.6429	1.5000	0.4902	1.4536	1.4494	1.4124	1.4227	1.4312	1.4536	1.4578	1.5000
1 1/2	16	N-3	0.5625	1.5000	1.4910	1.4594	1.4554	1.4233	1.4323	1.4403	1.4594	1.4634	1.5000
1 1/2	18	NEF-3	0.5000	1.5000	1.4918	1.4639	1.4601	1.4318	1.4399	1.4475	1.4639	1.4677	1.5000
1 1/2	20	NS-3	0.4500	1.5000	1.4928	1.4675	1.4638	1.4387	1.4459	1.4531	1.4675	1.4712	1.5000
1 1/2	24	NS-3	0.3750	1.5000	1.4934	1.4729	1.4694	1.4489	1.4549	1.4613	1.4729	1.4764	1.5000
1 9/16	16	N-3	0.5625	1.5625	1.5535	1.5219	1.5179	1.4858	1.4948	1.5028	1.5219	1.5259	1.5625
1 9/16	18	NEF-3	0.5000	1.5625	1.5543	1.5264	1.5225	1.4943	1.5024	1.5100	1.5264	1.5303	1.5625
1 5/8	6	NS-3	1.5000	1.6250	1.6048	1.5167	1.5107	1.4205	1.4446	1.4626	1.5167	1.5227	1.6250
1 5/8	7	NS-3	1.2857	1.6250	1.6080	1.5322	1.5266	1.4497	1.4704	1.4859	1.5322	1.5378	1.6250
1 5/8	8[b]	NS-3	1.1250	1.6250	1.6098	1.5438	1.5386	1.4716	1.4897	1.5032	1.5438	1.5490	1.6250
1 5/8	10	NS-3	0.9000	1.6250	1.6122	1.5600	1.5552	1.5023	1.5167	1.5275	1.5600	1.5648	1.6250
1 5/8	12	N-3	0.7500	1.6250	1.6138	1.5709	1.5664	1.5228	1.5348	1.5438	1.5709	1.5754	1.6250
1 5/8	14	NS-3	0.6429	1.6250	1.6152	1.5786	1.5744	1.5374	1.5477	1.5562	1.5786	1.5828	1.6250
1 5/8	16	N-3	0.5625	1.6250	1.6160	1.5844	1.5803	1.5483	1.5573	1.5653	1.5844	1.5885	1.6250
1 5/8	18	NEF-3	0.5000	1.6250	1.6168	1.5889	1.5850	1.5568	1.5649	1.5725	1.5889	1.5928	1.6250
1 5/8	20	NS-3	0.4500	1.6250	1.6178	1.5925	1.5888	1.5637	1.5709	1.5781	1.5925	1.5962	1.6250
1 5/8	24	NS-3	0.3750	1.6250	1.6184	1.5979	1.5944	1.5739	1.5799	1.5863	1.5979	1.6014	1.6250
1 11/16	16	N-3	0.5625	1.6875	1.6785	1.6469	1.6428	1.6108	1.6198	1.6278	1.6469	1.6510	1.6875
1 11/16	18	NEF-3	0.5000	1.6875	1.6793	1.6514	1.6475	1.6193	1.6274	1.6350	1.6514	1.6553	1.6875
1 3/4	6	NS-3	1.5000	1.7500	1.7298	1.6417	1.6356	1.5455	1.5696	1.5876	1.6417	1.6478	1.7500
1 3/4	7	NS-3	1.2857	1.7500	1.7330	1.6572	1.6515	1.5747	1.5954	1.6109	1.6572	1.6629	1.7500
1 3/4	8[b]	NS-3	1.1250	1.7500	1.7348	1.6688	1.6634	1.5966	1.6147	1.6282	1.6688	1.6742	1.7500
1 3/4	10	NS-3	0.9000	1.7500	1.7372	1.6850	1.6801	1.6273	1.6417	1.6525	1.6850	1.6899	1.7500
1 3/4	12	N-3	0.7500	1.7500	1.7388	1.6959	1.6913	1.6478	1.6598	1.6688	1.6959	1.7005	1.7500
1 3/4	14	NS-3	0.6429	1.7500	1.7402	1.7036	1.6993	1.6624	1.6727	1.6812	1.7036	1.7079	1.7500
1 3/4	16	NEF-3 N-3	0.5625	1.7500	1.7410	1.7094	1.7053	1.6733	1.6823	1.6903	1.7094	1.7135	1.7500
1 3/4	18	NS-3	0.5000	1.7500	1.7418	1.7139	1.7099	1.6818	1.6899	1.6975	1.7139	1.7179	1.7500
1 3/4	20	NS-3	0.4500	1.7500	1.7428	1.7175	1.7137	1.6887	1.6959	1.7031	1.7175	1.7213	1.7500
1 13/16	16	N-3	0.5625	1.8125	1.8035	1.7719	1.7677	1.7358	1.7448	1.7528	1.7719	1.7761	1.8125
1 7/8	6	NS-3	1.5000	1.8750	1.8548	1.7667	1.7606	1.6705	1.6946	1.7126	1.7667	1.7728	1.8750
1 7/8	7	NS-3	1.2857	1.8750	1.8580	1.7822	1.7765	1.6997	1.7204	1.7359	1.7822	1.7879	1.8750
1 7/8	8[b]	NS-3	1.1250	1.8750	1.8598	1.7938	1.7884	1.7216	1.7397	1.7532	1.7938	1.7992	1.8750
1 7/8	10	NS-3	0.9000	1.8750	1.8622	1.8100	1.8051	1.7523	1.7667	1.7775	1.8100	1.8149	1.8750
1 7/8	12	N-3	0.7500	1.8750	1.8638	1.8209	1.8163	1.7728	1.7848	1.7938	1.8209	1.8255	1.8750
1 7/8	14	NS-3	0.6429	1.8750	1.8652	1.8286	1.8243	1.7874	1.7977	1.8062	1.8286	1.8329	1.8750
1 7/8	16	N-3	0.5625	1.8750	1.8660	1.8344	1.8302	1.7983	1.8073	1.8153	1.8344	1.8386	1.8750
1 7/8	18	NS-3	0.5000	1.8750	1.8668	1.8389	1.8349	1.8068	1.8149	1.8225	1.8389	1.8429	1.8750
1 7/8	20	NS-3	0.4500	1.8750	1.8678	1.8425	1.8387	1.8137	1.8209	1.8281	1.8425	1.8463	1.8750
1 15/16	16	N-3	0.5625	1.9375	1.9285	1.8969	1.8927	1.8608	1.8698	1.8778	1.8969	1.9011	1.9375

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 20d—*Class 3, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
2	6	NS-3	1.5000	2.0000	1.9798	1.8917	1.8855	1.7955	1.8196	1.8376	1.8917	1.8979	2.0000
2	7	NS-3	1.2857	2.0000	1.9830	1.9072	1.9014	1.8247	1.8454	1.8609	1.9072	1.9130	2.0000
2	8[b]	NS-3	1.1250	2.0000	1.9848	1.9188	1.9133	1.8466	1.8647	1.8782	1.9188	1.9243	2.0000
2	10	NS-3	0.9000	2.0000	1.9872	1.9350	1.9300	1.8773	1.8917	1.9025	1.9350	1.9400	2.0000
2	12	N-3	0.7500	2.0000	1.9888	1.9459	1.9412	1.8978	1.9098	1.9188	1.9459	1.9506	2.0000
2	14	NS-3	0.6429	2.0000	1.9902	1.9536	1.9492	1.9124	1.9227	1.9312	1.9536	1.9580	2.0000
2	16	{NEF-3 N-3}	0.5625	2.0000	1.9910	1.9594	1.9551	1.9233	1.9323	1.9403	1.9594	1.9637	2.0000
2	18	NS-3	0.5000	2.0000	1.9918	1.9639	1.9598	1.9318	1.9399	1.9475	1.9639	1.9680	2.0000
2	20	NS-3	0.4500	2.0000	1.9928	1.9675	1.9635	1.9387	1.9459	1.9531	1.9675	1.9715	2.0000
2 1/16	16	N-3	0.5625	2.0625	2.0535	2.0219	2.0176	1.9858	1.9948	2.0028	2.0219	2.0262	2.0625
2 1/8	12	N-3	0.7500	2.1250	2.1138	2.0709	2.0661	2.0228	2.0348	2.0438	2.0709	2.0757	2.1250
2 1/8	16	N-3	0.5625	2.1250	2.1160	2.0844	2.0801	2.0483	2.0573	2.0653	2.0844	2.0887	2.1250
2 3/16	16	N-3	0.5625	2.1875	2.1785	2.1469	2.1426	2.1108	2.1198	2.1278	2.1469	2.1512	2.1875
2 1/4	6	NS-3	1.5000	2.2500	2.2298	2.1417	2.1355	2.0455	2.0696	2.0876	2.1417	2.1479	2.2500
2 1/4	7	NS-3	1.2857	2.2500	2.2330	2.1572	2.1514	2.0747	2.0954	2.1109	2.1572	2.1630	2.2500
2 1/4	8[b]	NS-3	1.1250	2.2500	2.2348	2.1688	2.1633	2.0966	2.1147	2.1282	2.1688	2.1743	2.2500
2 1/4	10	NS-3	0.9000	2.2500	2.2372	2.1850	2.1800	2.1273	2.1417	2.1525	2.1850	2.1900	2.2500
2 1/4	12	N-3	0.7500	2.2500	2.2388	2.1959	2.1911	2.1478	2.1598	2.1688	2.1959	2.2007	2.2500
2 1/4	14	NS-3	0.6429	2.2500	2.2402	2.2036	2.1992	2.1624	2.1727	2.1812	2.2036	2.2080	2.2500
2 1/4	16	N-3	0.5625	2.2500	2.2410	2.2094	2.2050	2.1733	2.1823	2.1903	2.2094	2.2138	2.2500
2 1/4	18	NS-3	0.5000	2.2500	2.2418	2.2139	2.2098	2.1818	2.1899	2.1975	2.2139	2.2180	2.2500
2 1/4	20	NS-3	0.4500	2.2500	2.2428	2.2175	2.2135	2.1887	2.1959	2.2031	2.2175	2.2215	2.2500
2 5/16	16	N-3	0.5625	2.3125	2.3035	2.2719	2.2675	2.2358	2.2448	2.2528	2.2719	2.2763	2.3125
2 3/8	12	N-3	0.7500	2.3750	2.3638	2.3209	2.3160	2.2728	2.2848	2.2938	2.3209	2.3258	2.3750
2 3/8	16	N-3	0.5625	2.3750	2.3660	2.3344	2.3300	2.2983	2.3073	2.3153	2.3344	2.3388	2.3750
2 7/16	16	N-3	0.5625	2.4375	2.4285	2.3969	2.3924	2.3608	2.3698	2.3778	2.3969	2.4014	2.4375
2 1/2	6	NS-3	1.5000	2.5000	2.4798	2.3917	2.3852	2.2955	2.3196	2.3376	2.3917	2.3982	2.5000
2 1/2	7	NS-3	1.2857	2.5000	2.4830	2.4072	2.4011	2.3247	2.3454	2.3609	2.4072	2.4133	2.5000
2 1/2	8[b]	NS-3	1.1250	2.5000	2.4848	2.4188	2.4131	2.3466	2.3647	2.3782	2.4188	2.4245	2.5000
2 1/2	10	NS-3	0.9000	2.5000	2.4872	2.4350	2.4297	2.3773	2.3917	2.4025	2.4350	2.4403	2.5000
2 1/2	12	N-3	0.7500	2.5000	2.4888	2.4459	2.4410	2.3978	2.4098	2.4188	2.4459	2.4508	2.5000
2 1/2	14	NS-3	0.6429	2.5000	2.4902	2.4536	2.4489	2.4124	2.4227	2.4312	2.4536	2.4583	2.5000
2 1/2	16	N-3	0.5625	2.5000	2.4910	2.4594	2.4549	2.4233	2.4323	2.4403	2.4594	2.4639	2.5000
2 1/2	18	NS-3	0.5000	2.5000	2.4918	2.4639	2.4596	2.4318	2.4399	2.4475	2.4639	2.4682	2.5000
2 1/2	20	NS-3	0.4500	2.5000	2.4928	2.4675	2.4633	2.4387	2.4459	2.4531	2.4675	2.4717	2.5000
2 5/8	12	N-3	0.7500	2.6250	2.6138	2.5709	2.5659	2.5228	2.5348	2.5438	2.5709	2.5759	2.6250
2 5/8	16	N-3	0.5625	2.6250	2.6160	2.5844	2.5799	2.5483	2.5573	2.5653	2.5844	2.5889	2.6250
2 3/4	6	NS-3	1.5000	2.7500	2.7298	2.6417	2.6352	2.5455	2.5696	2.5876	2.6417	2.6482	2.7500
2 3/4	7	NS-3	1.2857	2.7500	2.7330	2.6572	2.6511	2.5747	2.5954	2.6109	2.6572	2.6633	2.7500
2 3/4	8[b]	NS-3	1.1250	2.7500	2.7348	2.6688	2.6631	2.5966	2.6147	2.6282	2.6688	2.6745	2.7500
2 3/4	10	NS-3	0.9000	2.7500	2.7372	2.6850	2.6797	2.6273	2.6417	2.6525	2.6850	2.6903	2.7500
2 3/4	12	N-3	0.7500	2.7500	2.7388	2.6959	2.6909	2.6478	2.6598	2.6688	2.6959	2.7009	2.7500
2 3/4	14	NS-3	0.6429	2.7500	2.7402	2.7036	2.6989	2.6624	2.6727	2.6812	2.7036	2.7083	2.7500
2 3/4	16	N-3	0.5625	2.7500	2.7410	2.7094	2.7048	2.6733	2.6823	2.6903	2.7094	2.7140	2.7500
2 3/4	18	NS-3	0.5000	2.7500	2.7418	2.7139	2.7096	2.6818	2.6899	2.6875	2.7139	2.7182	2.7500
2 7/8	12	N-3	0.7500	2.8750	2.8638	2.8209	2.8158	2.7728	2.7848	2.7938	2.8209	2.8260	2.8750
2 7/8	16	N-3	0.5625	2.8750	2.8660	2.8344	2.8298	2.7983	2.8073	2.8153	2.8344	2.8390	2.8750
3	6	NS-3	1.5000	3.0000	2.9798	2.8917	2.8850	2.7955	2.8196	2.8376	2.8917	2.8984	3.0000
3	7	NS-3	1.2857	3.0000	2.9830	2.9072	2.9009	2.8247	2.8454	2.8609	2.9072	2.9135	3.0000
3	8[b]	NS-3	1.1250	3.0000	2.9848	2.9188	2.9129	2.8466	2.8647	2.8782	2.9188	2.9247	3.0000
3	10	NS-3	0.9000	3.0000	2.9872	2.9350	2.9295	2.8773	2.8917	2.9025	2.9350	2.9405	3.0000
3	12	N-3	0.7500	3.0000	2.9888	2.9459	2.9408	2.8978	2.9098	2.9188	2.9459	2.9510	3.0000
3	14	NS-3	0.6429	3.0000	2.9902	2.9536	2.9487	2.9124	2.9227	2.9312	2.9536	2.9585	3.0000
3	16	N-3	0.5625	3.0000	2.9910	2.9594	2.9547	2.9233	2.9323	2.9403	2.9594	2.9641	3.0000
3	18	NS-3	0.5000	3.0000	2.9919	2.9639	2.9594	2.9318	2.9399	2.9475	2.9639	2.9684	3.0000

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 20e—*Class 3, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
3 1/8	12	N-3	0.7500	3.1250	3.1138	3.0709	3.0657	3.0228	3.0348	3.0438	3.0709	3.0761	3.1250
3 1/8	16	N-3	0.5625	3.1250	3.1160	3.0844	3.0797	3.0483	3.0573	3.0653	3.0844	3.0891	3.1250
3 1/4	6	NS-3	1.5000	3.2500	3.2298	3.1417	3.1350	3.0455	3.0696	3.0876	3.1417	3.1484	3.2500
3 1/4	7	NS-3	1.2857	3.2500	3.2330	3.1572	3.1509	3.0747	3.0954	3.1109	3.1572	3.1635	3.2500
3 1/4	8[b]	NS-3	1.1250	3.2500	3.2348	3.1688	3.1628	3.0966	3.1147	3.1282	3.1688	3.1748	3.2500
3 1/4	10	NS-3	0.9000	3.2500	3.2372	3.1850	3.1795	3.1273	3.1417	3.1525	3.1850	3.1905	3.2500
3 1/4	12	N-3	0.7500	3.2500	3.2388	3.1959	3.1907	3.1478	3.1598	3.1688	3.1959	3.2011	3.2500
3 1/4	14	NS-3	0.6429	3.2500	3.2402	3.2036	3.1987	3.1624	3.1727	3.1812	3.2036	3.2085	3.2500
3 1/4	16	N-3	0.5625	3.2500	3.2410	3.2094	3.2046	3.1733	3.1823	3.1903	3.2094	3.2142	3.2500
3 1/4	18	NS-3	0.5000	3.2500	3.2418	3.2139	3.2094	3.1818	3.1899	3.1975	3.2139	3.2184	3.2500
3 3/8	12	N-3	0.7500	3.3750	3.3638	3.3209	3.3156	3.2728	3.2848	3.2938	3.3209	3.3262	3.3750
3 3/8	16	N-3	0.5625	3.3750	3.3660	3.3344	3.3296	3.2983	3.3073	3.3153	3.3344	3.3392	3.3750
3 1/2	6	NS-3	1.5000	3.5000	3.4798	3.3917	3.3848	3.2955	3.3196	3.3376	3.3917	3.3986	3.5000
3 1/2	7	NS-3	1.2857	3.5000	3.4830	3.4072	3.4007	3.3247	3.3454	3.3609	3.4072	3.4137	3.5000
3 1/2	8[b]	NS-3	1.1250	3.5000	3.4848	3.4188	3.4127	3.3466	3.3647	3.3782	3.4188	3.4249	3.5000
3 1/2	10	NS-3	0.9000	3.5000	3.4872	3.4350	3.4293	3.3773	3.3917	3.4025	3.4350	3.4407	3.5000
3 1/2	12	N-3	0.7500	3.5000	3.4888	3.4459	3.4406	3.3978	3.4098	3.4188	3.4459	3.4512	3.5000
3 1/2	14	NS-3	0.6429	3.5000	3.4902	3.4536	3.4485	3.4124	3.4227	3.4312	3.4536	3.4587	3.5000
3 1/2	16	N-3	0.5625	3.5000	3.4910	3.4594	3.4545	3.4233	3.4323	3.4403	3.4594	3.4643	3.5000
3 1/2	18	NS-3	0.5000	3.5000	3.4918	3.4639	3.4592	3.4318	3.4399	3.4475	3.4639	3.4686	3.5000
3 5/8	12	N-3	0.7500	3.6250	3.6138	3.5709	3.5655	3.5228	3.5348	3.5438	3.5709	3.5673	3.6250
3 5/8	16	N-3	0.5625	3.6250	3.6160	3.5844	3.5795	3.5483	3.5573	3.5653	3.5844	3.5893	3.6250
3 3/4	6	NS-3	1.5000	3.7500	3.7298	3.6417	3.6348	3.5455	3.5696	3.5876	3.6417	3.6486	3.7500
3 3/4	7	NS-3	1.2857	3.7500	3.7330	3.6572	3.6507	3.5747	3.5954	3.6109	3.6572	3.6637	3.7500
3 3/4	8[b]	NS-3	1.1250	3.7500	3.7348	3.6688	3.6627	3.5966	3.6147	3.6282	3.6688	3.6749	3.7500
3 3/4	10	NS-3	0.9000	3.7500	3.7372	3.6850	3.6793	3.6273	3.6417	3.6525	3.6850	3.6907	3.7500
3 3/4	12	N-3	0.7500	3.7500	3.7388	3.6959	3.6905	3.6478	3.6598	3.6688	3.6959	3.7013	3.7500
3 3/4	14	NS-3	0.6429	3.7500	3.7402	3.7036	3.6985	3.6624	3.6727	3.6812	3.7036	3.7087	3.7500
3 3/4	16	N-3	0.5625	3.7500	3.7410	3.7094	3.7044	3.6733	3.6823	3.6903	3.7094	3.7144	3.7500
3 3/4	18	NS-3	0.5000	3.7500	3.7418	3.7139	3.7092	3.6818	3.6899	3.6975	3.7139	3.7186	3.7500
3 7/8	12	N-3	0.7500	3.8750	3.8638	3.8209	3.8154	3.7728	3.7848	3.7938	3.8209	3.8264	3.8750
3 7/8	16	N-3	0.5625	3.8750	3.8660	3.8344	3.8294	3.7983	3.8073	3.8153	3.8344	3.8394	3.8750
4	6	NS-3	1.5000	4.0000	3.9798	3.8917	3.8846	3.7955	3.8196	3.8376	3.8917	3.8988	4.0000
4	7	NS-3	1.2857	4.0000	3.9830	3.9072	3.9006	3.8247	3.8454	3.8609	3.9072	3.9138	4.0000
4	8[b]	NS-3	1.1250	4.0000	3.9848	3.9188	3.9125	3.8466	3.8647	3.8782	3.9188	3.9251	4.0000
4	10	NS-3	0.9000	4.0000	3.9872	3.9350	3.9291	3.8773	3.8917	3.9025	3.9350	3.9409	4.0000
4	12	N-3	0.7500	4.0000	3.9888	3.9459	3.9404	3.8978	3.9098	3.9188	3.9459	3.9514	4.0000
4	14	NS-3	0.6429	4.0000	3.9902	3.9536	3.9483	3.9124	3.9227	3.9312	3.9536	3.9589	4.0000
4	16	N-3	0.5625	4.0000	3.9910	3.9594	3.9543	3.9233	3.9323	3.9403	3.9594	3.9645	4.0000
4 1/4	4	NS-3	2.2500	4.2500	4.2220	4.0876	4.0792	3.9433	3.9794	4.0065	4.0876	4.0960	4.2500
4 1/4	6	NS-3	1.5000	4.2500	4.2298	4.1417	4.1346	4.0455	4.0696	4.0876	4.1417	4.1488	4.2500
4 1/4	7	NS-3	1.2857	4.2500	4.2330	4.1572	4.1506	4.0747	4.0954	4.1109	4.1572	4.1638	4.2500
4 1/4	8[b]	NS-3	1.1250	4.2500	4.2348	4.1688	4.1625	4.0966	4.1147	4.1282	4.1688	4.1751	4.2500
4 1/4	10	NS-3	0.9000	4.2500	4.2372	4.1850	4.1791	4.1273	4.1417	4.1525	4.1850	4.1909	4.2500
4 1/4	12	N-3	0.7500	4.2500	4.2388	4.1959	4.1903	4.1478	4.1598	4.1688	4.1959	4.2015	4.2500
4 1/4	14	NS-3	0.6429	4.2500	4.2402	4.2036	4.1983	4.1624	4.1727	4.1812	4.2036	4.2089	4.2500
4 1/4	16	N-3	0.5625	4.2500	4.2410	4.2094	4.2042	4.1733	4.1823	4.1903	4.2094	4.2146	4.2500
4 1/2	4	NS-3	2.2500	4.5000	4.4720	4.3376	4.3292	4.1933	4.2294	4.2565	4.3376	4.3460	4.5000
4 1/2	6	NS-3	1.5000	4.5000	4.4798	4.3917	4.3846	4.2955	4.3196	4.3376	4.3917	4.3988	4.5000
4 1/2	7	NS-3	1.2857	4.5000	4.4830	4.4072	4.4006	4.3247	4.3454	4.3609	4.4072	4.4138	4.5000
4 1/2	8[b]	NS-3	1.1250	4.5000	4.4848	4.4188	4.4125	4.3466	4.3647	4.3782	4.4188	4.4251	4.5000
4 1/2	10	NS-3	0.9000	4.5000	4.4872	4.4350	4.4291	4.3773	4.3917	4.4025	4.4350	4.4409	4.5000
4 1/2	12	N-3	0.7500	4.5000	4.4888	4.4459	4.4402	4.3978	4.4098	4.4188	4.4459	4.4516	4.5000
4 1/2	14	NS-3	0.6429	4.5000	4.4902	4.4536	4.4483	4.4124	4.4227	4.4312	4.4536	4.4589	4.5000
4 1/2	16	N-3	0.5625	4.5000	4.4910	4.4594	4.4541	4.4233	4.4323	4.4403	4.4594	4.4647	4.5000

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

TABLE 20f—*Class 3, Selected Combinations of Special Diameter and Pitch—N, NEF, and NS*

DESIGNATION			L_e, 9 × PITCH	EXTERNAL-THREAD LIMITS OF SIZE					INTERNAL-THREAD LIMITS OF SIZE				
Size	Threads per inch	Thread symbol		Major diameter		Pitch diameter		Minor diameter[a]	Minor diameter		Pitch diameter		Major diameter
				Max	Min	Max	Min		Min	Max	Min	Max	Min
4¾	4	NS-3	2.2500	4.7500	4.7220	4.5876	4.5789	4.4433	4.4794	4.5065	4.5876	4.5963	4.7500
4¾	6	NS-3	1.5000	4.7500	4.7298	4.6417	4.6343	4.5455	4.5696	4.5876	4.6417	4.6491	4.7500
4¾	7	NS-3	1.2857	4.7500	4.7330	4.6572	4.6502	4.5747	4.5954	4.6109	4.6572	4.6642	4.7500
4¾	8[b]	NS-3	1.1250	4.7500	4.7348	4.6688	4.6621	4.5966	4.6147	4.6282	4.6688	4.6755	4.7500
4¾	10	NS-3	0.9000	4.7500	4.7372	4.6850	4.6788	4.6273	4.6417	4.6525	4.6850	4.6912	4.7500
4¾	12	N-3	0.7500	4.7500	4.7388	4.6959	4.6901	4.6478	4.6598	4.6688	4.6959	4.7017	4.7500
4¾	14	NS-3	0.6429	4.7500	4.7402	4.7036	4.6980	4.6624	4.6727	4.6812	4.7036	4.7092	4.7500
4¾	16	N-3	0.5625	4.7500	4.7410	4.7094	4.7041	4.6733	4.6823	4.6903	4.7094	4.7147	4.7500
5	4	NS-3	2.2500	5.0000	4.9720	4.8376	4.8289	4.6933	4.7294	4.7565	4.8376	4.8463	5.0000
5	6	NS-3	1.5000	5.0000	4.9798	4.8917	4.8843	4.7955	4.8196	4.8376	4.8917	4.8991	5.0000
5	7	NS-3	1.2857	5.0000	4.9830	4.9072	4.9002	4.8247	4.8454	4.8609	4.9072	4.9142	5.0000
5	8[b]	NS-3	1.1250	5.0000	4.9848	4.9188	4.9121	4.8466	4.8647	4.8782	4.9188	4.9255	5.0000
5	10	NS-3	0.9000	5.0000	4.9872	4.9350	4.9288	4.8773	4.8917	4.9025	4.9350	4.9412	5.0000
5	12	N-3	0.7500	5.0000	4.9888	4.9459	4.9400	4.8978	4.9098	4.9188	4.9459	4.9518	5.0000
5	14	NS-3	0.6429	5.0000	4.9902	4.9536	4.9480	4.9124	4.9227	4.9312	4.9536	4.9592	5.0000
5	16	N-3	0.5625	5.0000	4.9910	4.9594	4.9540	4.9233	4.9323	4.9403	4.9594	4.9648	5.0000
5¼	4	NS-3	2.2500	5.2500	5.2220	5.0876	5.0789	4.9433	4.9794	5.0065	5.0876	5.0963	5.2500
5¼	6	NS-3	1.5000	5.2500	5.2298	5.1417	5.1343	5.0455	5.0696	5.0876	5.1417	5.1491	5.2500
5¼	7	NS-3	1.2857	5.2500	5.2330	5.1572	5.1502	5.0747	5.0954	5.1109	5.1572	5.1642	5.2500
5¼	8[b]	NS-3	1.1250	5.2500	5.2348	5.1688	5.1621	5.0966	5.1147	5.1282	5.1688	5.1755	5.2500
5¼	10	NS-3	0.9000	5.2500	5.2372	5.1850	5.1788	5.1273	5.1417	5.1525	5.1850	5.1912	5.2500
5¼	12	N-3	0.7500	5.2500	5.2388	5.1959	5.1900	5.1478	5.1598	5.1688	5.1959	5.2018	5.2500
5¼	14	NS-3	0.6429	5.2500	5.2402	5.2036	5.1980	5.1624	5.1727	5.1812	5.2036	5.2092	5.2500
5¼	16	N-3	0.5625	5.2500	5.2410	5.2094	5.2039	5.1733	5.1823	5.1903	5.2094	5.2149	5.2500
5½	4	NS-3	2.2500	5.5000	5.4720	5.3376	5.3289	5.1933	5.2294	5.2565	5.3376	5.3463	5.5000
5½	6	NS-3	1.5000	5.5000	5.4798	5.3917	5.3843	5.2955	5.3196	5.3376	5.3917	5.3991	5.5000
5½	7	NS-3	1.2857	5.5000	5.4830	5.4072	5.4002	5.3247	5.3454	5.3609	5.4072	5.4142	5.5000
5½	8[b]	NS-3	1.1250	5.5000	5.4848	5.4188	5.4121	5.3466	5.3647	5.3782	5.4188	5.4255	5.5000
5½	10	NS-3	0.9000	5.5000	5.4872	5.4350	5.4288	5.3773	5.3917	5.4025	5.4350	5.4412	5.5000
5½	12	N-3	0.7500	5.5000	5.4888	5.4459	5.4399	5.3978	5.4098	5.4188	5.4459	5.4519	5.5000
5½	14	NS-3	0.6429	5.5000	5.4902	5.4536	5.4480	5.4124	5.4227	5.4312	5.4536	5.4592	5.5000
5½	16	N-3	0.5625	5.5000	5.4910	5.4594	5.4538	5.4233	5.4323	5.4403	5.4594	5.4650	5.5000
5¾	4	NS-3	2.2500	5.7500	5.7220	5.5876	5.5786	5.4433	5.4794	5.5065	5.5876	5.5966	5.7500
5¾	6	NS-3	1.5000	5.7500	5.7298	5.6417	5.6340	5.5455	5.5696	5.5876	5.6417	5.6494	5.7500
5¾	7	NS-3	1.2857	5.7500	5.7330	5.6572	5.6499	5.5747	5.5954	5.6109	5.6572	5.6645	5.7500
5¾	8[b]	NS-3	1.1250	5.7500	5.7348	5.6688	5.6618	5.5966	5.6147	5.6282	5.6688	5.6758	5.7500
5¾	10	NS-3	0.9000	5.7500	5.7372	5.6850	5.6785	5.6273	5.6417	5.6525	5.6850	5.6915	5.7500
5¾	12	N-3	0.7500	5.7500	5.7388	5.6959	5.6898	5.6478	5.6598	5.6688	5.6959	5.7020	5.7500
5¾	14	NS-3	0.6429	5.7500	5.7402	5.7036	5.6977	5.6624	5.6727	5.6812	5.7036	5.7095	5.7500
5¾	16	N-3	0.5625	5.7500	5.7410	5.7094	5.7038	5.6733	5.6823	5.6903	5.7094	5.7150	5.7500
6	4	NS-3	2.2500	6.0000	5.9720	5.8376	5.8286	5.6933	5.7294	5.7565	5.8376	5.8466	6.0000
6	6	NS-3	1.5000	6.0000	5.9798	5.8917	5.8840	5.7955	5.8196	5.8376	5.8917	5.8994	6.0000
6	7	NS-3	1.2857	6.0000	5.9830	5.9072	5.8999	5.8247	5.8474	5.8609	5.9072	5.9145	6.0000
6	8[b]	NS-3	1.1250	6.0000	5.9848	5.9188	5.9118	5.8466	5.8647	5.8782	5.9188	5.9258	6.0000
6	10	NS-3	0.9000	6.0000	5.9872	5.9350	5.9285	5.8773	5.8917	5.9025	5.9350	5.9415	6.0000
6	12	N-3	0.7500	6.0000	5.9888	5.9459	5.9397	5.8978	5.9098	5.9188	5.9459	5.9521	6.0000
6	14	NS-3	0.6429	6.0000	5.9902	5.9536	5.9477	5.9124	5.9227	5.9312	5.9536	5.9595	6.0000
6	16	N-3	0.5625	6.0000	5.9910	5.9594	5 9537	5.9233	5.9323	5.9403	5.9594	5.9651	6.0000

[a] See Fig. 1.
[b] For special applications where tolerances based on a 9-thread length of engagement are more suitable than those of the standard 8-pitch series.

Outline Guide for Determining Limiting Dimensions of Special External Threads

THREAD CLASSES	MAJOR DIAMETER (D_s OR B_s)		PITCH DIAMETER (E_s)		MINOR DIAMETER (K_s)
Unified and American	Maximum	Minimum	Maximum	Minimum	
1A	Nominal size minus allowance (Table 22) for diameter and pitch of respective thread	Maximum minus tolerance (Table 21, Col 2 and 6)	Maximum major diameter minus h_b (Table 1, Col 15)	Maximum minus tolerance (Table 23 or Table 33) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and minimum minor diameter of Go-ring gage
2A	Nominal size minus allowance (Table 22) for diameter and pitch of respective thread	Maximum minus tolerance (Table 21, Col 3 and 7)	Maximum major diameter minus h_b (Table 1, Col 15)	Maximum minus tolerance (Table 24 or Table 33) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and minimum minor diameter of Go-ring gage
3A	Nominal size	Maximum minus tolerance (Table 21, Col 3 and 7)	Maximum major diameter minus h_b (Table 1, Col 15)	Maximum minus tolerance (Table 25 or Table 33) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and minimum minor diameter of Go-ring gage
1	Nominal size minus allowance (Table 35, Col 2)	Maximum minus tolerance (Table 35, Col 3)	Maximum major diameter minus h_b (Table 1, Col 15)	Maximum minus tolerance (Table 36) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and minimum minor diameter of Go-ring gage
2	Nominal size	Maximum minus tolerance (Table 21, Col 4 and 8)	Maximum major diameter minus h_b (Table 1, Col 15)	Maximum minus tolerance (Table 29 or Table 34) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and minimum minor diameter of Go-ring gage
3	Nominal size	Maximum minus tolerance (Table 21, Col 4 and 8)	Maximum major diameter minus h_b (Table 1, Col 15)	Maximum minus tolerance (Table 30 or Table 34) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and minimum minor diameter of Go-ring gage

Outline Guide for Determining Limiting Dimensions of Special Internal Threads

THREAD CLASSES	MINOR DIAMETER (K_n)		PITCH DIAMETER (E_n)		MAJOR DIAMETER (D_n OR B_n)
Unified and American	Minimum	Maximum	Minimum	Maximum	
1B	Nominal size minus $2h_n$ (Table 1, Col 5)	Minimum plus tolerance (Table 31) for diameter, pitch, and length of engagement of respective thread	Nominal size minus h_b (Table 1, Col 15)	Minimum plus tolerance (Table 26 or Table 33) for diameter, pitch, and length of engagement	Not specified, being established by crest of new tool and maximum major diameter of Go-plug thread gage
2B	Nominal size minus $2h_n$ (Table 1, Col 5)	Minimum plus tolerance (Table 31) for diameter, pitch, and length of engagement of respective thread	Nominal size minus h_b (Table 1, Col 15)	Minimum plus tolerance (Table 27 or Table 33) for diameter, pitch, and length of engagement	Not specified, being established by crest of new tool and maximum major diameter of Go-plug gage
3B	Nominal size minus $2h_n$ (Table 1, Col 5)	Minimum plus tolerance (Table 31) for diameter, pitch, and length of engagement of respective thread	Nominal size minus h_b (Table 1, Col 15)	Minimum plus tolerance (Table 28 or Table 33) for diameter, pitch, and length of engagement	Not specified, being established by crest of new tool and maximum major diameter of Go-plug gage
1	Nominal size minus $2h_n$ (Table 1, Col 5)	Minimum plus tolerance (Table 35, Col 7)	Nominal size minus h_b (Table 1, Col 15)	Minimum plus tolerance (Table 36) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and maximum major diameter of Go-plug gage
2	Nominal size minus $2h_n$ (Table 1, Col 5)	Minimum plus tolerance (Table 32) for diameter, pitch, and length of engagement of respective thread	Nominal size minus h_b (Table 1, Col 15)	Minimum plus tolerance (Table 29 or Table 34) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and maximum major diameter of Go-plug gage
3	Nominal size minus $2h_n$ (Table 1, Col 5)	Minimum plus tolerance (Table 32) for diameter, pitch, and length of engagement of respective thread	Nominal size minus h_b (Table 1, Col 15)	Minimum plus tolerance (Table 30 or Table 34) for diameter, pitch, and length of engagement of respective thread	Not specified, being established by crest of new tool and maximum major diameter of Go-plug gage

TABLE 21—*Major-Diameter Tolerances for External Threads of Special Diameters, Pitches, and Lengths of Engagement, Classes 1A, 2A, 3A, 2, and 3*

THREADS PER INCH	MAJOR-DIAMETER TOLERANCE			THREADS PER INCH	MAJOR-DIAMETER TOLERANCE		
	Class 1A	Class 2A Class 3A	Class 2 Class 3		Class 1A	Class 2A Class 3A	Class 2 Class 3
80	—	0.0032	0.0034	20	0.0122	0.0081	0.0072
72	—	0.0035	0.0036	18	0.0131	0.0087	0.0082
64	—	0.0038	0.0038	16	0.0142	0.0094	0.0090
56	—	0.0041	0.0040	14	0.0155	0.0103	0.0098
48	—	0.0045	0.0040	12	0.0172	0.0114	0.0112
40	0.0077	0.0051	0.0048	10	0.0194	0.0129	0.0128
36	0.0083	0.0055	0.0050	8	0.0225	0.0150	0.0152
32	0.0089	0.0060	0.0054	7	0.0246	0.0164	0.0170
28	0.0098	0.0065	0.0062	6	0.0273	0.0182	0.0202
24	0.0108	0.0072	0.0066	4	0.0357	0.0238	0.0280

TABLE 22—*Classes 1A and 2A, Allowances for External Threads of Special Diameters and Pitches—UNS and NS*

THREADS PER INCH	PITCH-DIAMETER[a] ALLOWANCES[b]											
	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	5/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750	1 0.8751 to 1.1250	1 1/4 1.1251 to 1.3750	1 1/2 1.3751 to 1.6250
80	0.0006	0.0006	0.0006	0.0007	0.0007	—	—	—	—	—	—	—
72	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007	—	—	—	—	—	—
64	0.0006	0.0007	0.0007	0.0007	0.0007	0.0008	0.0008	—	—	—	—	—
56	—	0.0007	0.0007	0.0007	0.0008	0.0008	0.0009	0.0009	0.0009	—	—	—
48	—	0.0007	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0009	—	—	—
40	—	—	0.0008	0.0009	0.0009	0.0009	0.0010	0.0010	0.0010	0.0010	—	—
36	—	—	0.0009	0.0009	0.0009	0.0010	0.0010	0.0010	0.0010	0.0011	0.0011	0.0012
32	—	—	0.0009	0.0009	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011	0.0012	0.0012
28	—	—	—	0.0010	0.0010	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013
24	—	—	—	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013
20	—	—	—	—	0.0012	0.0012	0.0013	0.0013	0.0013	0.0014	0.0014	0.0014
18	—	—	—	—	—	0.0013	0.0013	0.0014	0.0014	0.0014	0.0015	0.0015
16	—	—	—	—	—	0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0016
14	—	—	—	—	—	—	0.0015	0.0015	0.0015	0.0016	0.0016	0.0017
12	—	—	—	—	—	—	0.0016	0.0016	0.0017	0.0017	0.0017	0.0018
10	—	—	—	—	—	—	—	—	0.0018	0.0018	0.0019	0.0019
8	—	—	—	—	—	—	—	—	—	0.0021	0.0021	0.0021
6	—	—	—	—	—	—	—	—	—	—	—	0.0024
4	—	—	—	—	—	—	—	—	—	—	—	—

PITCH-DIAMETER[a] ALLOWANCES[b]											THREADS PER INCH
1 3/4 1.6251 to 1.8750	2 1.8751 to 2.2500	2 1/2 2.2501 to 2.7500	3 2.7501 to 3.2500	3 1/2 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	
—	—	—	—	—	—	—	—	—	—	—	80
—	—	—	—	—	—	—	—	—	—	—	72
—	—	—	—								64
—	—	—	—								56
—	—	—	—								48
—	—	—	—								40
—	—	—	—								36
0.0012	0.0013	0.0013	0.0013								32
0.0013	0.0013	0.0014	0.0014	0.0014	0.0015	—	—	—	—	—	28
0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0016	0.0016	—	—	—	24
0.0015	0.0015	0.0015	0.0016	0.0016	0.0016	0.0017	0.0017	—	—	—	20
0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0017	0.0018	0.0019	—	—	18
0.0016	0.0016	0.0017	0.0017	0.0017	0.0018	0.0018	0.0019	0.0019	0.0020	—	16
0.0017	0.0017	0.0017	0.0018	0.0018	0.0018	0.0019	0.0020	0.0020	0.0021	0.0022	14
0.0018	0.0018	0.0019	0.0019	0.0019	0.0020	0.0020	0.0021	0.0021	0.0022	0.0023	12
0.0019	0.0020	0.0020	0.0020	0.0021	0.0021	0.0022	0.0022	0.0023	0.0024	0.0024	10
0.0021	0.0022	0.0022	0.0023	0.0023	0.0023	0.0024	0.0024	0.0025	0.0026	0.0026	8
0.0025	0.0025	0.0025	0.0026	0.0026	0.0026	0.0027	0.0027	0.0028	0.0029	0.0029	6
—	0.0030	0.0031	0.0031	0.0031	0.0032	0.0032	0.0033	0.0034	0.0034	0.0035	4

NOTES

Classes 1A and 2A allowances are determined by multiplying Class 2A pitch-diameter tolerances (computed to six decimal places) by 0.3 and are based on lengths of engagement of nine pitches.

[a] British: Effective Diameter.
[b] Allowances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

TABLE 23—*Class 1A, Pitch-Diameter Tolerances for External Threads*

THREADS PER INCH	LENGTHS OF ENGAGEMENT		PITCH-DIAMETER[a] TOLERANCES[b]								
	Number of pitches	Inches	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	3/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750
80	5 to 15	0.06 to 0.19	—	—	—	—	—	—	—	—	—
	16 to 30	0.191 to 0.38	—	—	—	—	—	—	—	—	—
72	5 to 15	0.07 to 0.21	—	—	—	—	—	—	—	—	—
	16 to 30	0.211 to 0.42	—	—	—	—	—	—	—	—	—
64	5 to 15	0.08 to 0.23	—	—	—	—	—	—	—	—	—
	16 to 30	0.231 to 0.46	—	—	—	—	—	—	—	—	—
56	5 to 15	0.09 to 0.27	—	—	—	—	—	—	—	—	—
	16 to 30	0.271 to 0.54	—	—	—	—	—	—	—	—	—
48	5 to 15	0.10 to 0.31	—	—	—	—	—	—	—	—	—
	16 to 30	0.311 to 0.62	—	—	—	—	—	—	—	—	—
40	5 to 15	0.12 to 0.38	—	—	0.0041	0.0043	0.0044	0.0046	0.0048	0.0049	0.0050
	16 to 30	0.381 to 0.76	—	—	0.0046	0.0048	0.0049	0.0051	0.0053	0.0054	0.0056
36	5 to 15	0.14 to 0.42	—	—	0.0043	0.0045	0.0046	0.0048	0.0050	0.0051	0.0052
	16 to 30	0.421 to 0.84	—	—	—	0.0050	0.0052	0.0054	0.0055	0.0057	0.0058
32	5 to 15	0.16 to 0.47	—	—	0.0045	0.0047	0.0048	0.0050	0.0052	0.0053	0.0055
	16 to 30	0.471 to 0.94	—	—	—	0.0053	0.0054	0.0056	0.0058	0.0059	0.0061
28	5 to 15	0.18 to 0.54	—	—	—	0.0050	0.0051	0.0053	0.0055	0.0056	0.0058
	16 to 30	0.541 to 1.08	—	—	—	0.0056	0.0058	0.0060	0.0061	0.0063	0.0064
24	5 to 15	0.21 to 0.62	—	—	—	0.0054	0.0055	0.0057	0.0059	0.0060	0.0061
	16 to 30	0.621 to 1.24	—	—	—	—	0.0062	0.0064	0.0065	0.0067	0.0068
20	5 to 15	0.25 to 0.75	—	—	—	—	0.0060	0.0062	0.0063	0.0065	0.0066
	16 to 30	0.751 to 1.50	—	—	—	—	0.0067	0.0069	0.0071	0.0072	0.0073
18	5 to 15	0.28 to 0.83	—	—	—	—	—	0.0065	0.0067	0.0068	0.0069
	16 to 30	0.831 to 1.66	—	—	—	—	—	0.0073	0.0074	0.0076	0.0077
16	5 to 15	0.31 to 0.94	—	—	—	—	—	0.0069	0.0070	0.0072	0.0073
	16 to 30	0.941 to 1.88	—	—	—	—	—	0.0076	0.0077	0.0079	0.0080
14	5 to 15	0.36 to 1.07	—	—	—	—	—	—	0.0075	0.0076	0.0077
	16 to 30	1.071 to 2.14	—	—	—	—	—	—	0.0083	0.0085	0.0086
12	5 to 15	0.42 to 1.25	—	—	—	—	—	—	0.0080	0.0082	0.0083
	16 to 30	1.251 to 2.50	—	—	—	—	—	—	0.0090	0.0091	0.0092
10	5 to 15	0.50 to 1.50	—	—	—	—	—	—	—	—	0.0090
	16 to 30	1.501 to 3.00	—	—	—	—	—	—	—	—	0.0101
8	5 to 15	0.62 to 1.88	—	—	—	—	—	—	—	—	—
	16 to 30	1.881 to 3.76	—	—	—	—	—	—	—	—	—
7	5 to 15	0.71 to 2.14	—	—	—	—	—	—	—	—	—
	16 to 30	2.141 to 4.29	—	—	—	—	—	—	—	—	—
6	5 to 15	0.83 to 2.50	—	—	—	—	—	—	—	—	—
	16 to 30	2.501 to 5.00	—	—	—	—	—	—	—	—	—
4	5 to 15	1.25 to 3.75	—	—	—	—	—	—	—	—	—
	16 to 30	3.751 to 7.50	—	—	—	—	—	—	—	—	—

[a] British: Effective Diameter.
[b] Tolerances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

of Special Diameters, Pitches, and Lengths of Engagement—UNS and NS

PITCH-DIAMETER[a] TOLERANCES[b]													THREADS PER INCH
1 0.8751 to 1.1250	1¼ 1.1251 to 1.3750	1½ 1.3751 to 1.6250	1¾ 1.6251 to 1.8750	2 1.8751 to 2.2500	2½ 2.2501 to 2.7500	3 2.7501 to 3.2500	3½ 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	
—	—	—	NOTES											80
—	—	—	1. These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8N thread series.											
—	—	—	2. Formula:											72
—	—	—	Class 1A tolerances for external threads are determined by multiplying Class 2A tolerances (computed to six decimal places) by 1.500. See Note 2, Table 24, for formula for Class 2A tolerances.											
—	—	—	3. Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement from 16 to 30 pitches are based on lengths of 20 pitches. For lengths of engagement not tabulated, the formula in Note 2 should be applied.											64
—	—	—	4. Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Note 2 should be applied.											56
—	—	—	5. Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement which are considered to be generally used. For other combinations encountered, see Limitations of Design, Appendix D.											48
0.0052	—	—												40
0.0058	—	—												
0.0054	0.0056	0.0058	—	—	—	—	—	—	—	—	—	—	—	36
0.0060	0.0062	0.0063	—	—	—	—	—	—	—	—	—	—	—	
0.0057	0.0058	0.0060	0.0061	0.0063	0.0065	0.0067	—	—	—	—	—	—	—	32
0.0063	0.0064	0.0066	0.0067	0.0068	0.0071	0.0073	—	—	—	—	—	—	—	
0.0060	0.0061	0.0063	0.0064	0.0066	0.0068	0.0070	0.0071	0.0073	—	—	—	—	—	28
0.0066	0.0068	0.0069	0.0071	0.0072	0.0074	0.0076	0.0078	0.0079	—	—	—	—	—	
0.0063	0.0065	0.0067	0.0068	0.0069	0.0071	0.0073	0.0075	0.0077	0.0079	0.0082	—	—	—	24
0.0070	0.0072	0.0073	0.0075	0.0076	0.0078	0.0080	0.0082	0.0083	0.0086	0.0088	—	—	—	
0.0068	0.0070	0.0071	0.0073	0.0074	0.0076	0.0078	0.0080	0.0081	0.0084	0.0087	—	—	—	20
0.0076	0.0077	0.0079	0.0080	0.0081	0.0084	0.0085	0.0087	0.0089	0.0092	0.0094	—	—	—	
0.0071	0.0073	0.0074	0.0076	0.0077	0.0079	0.0081	0.0083	0.0084	0.0087	0.0090	0.0094	—	—	18
0.0079	0.0081	0.0082	0.0084	0.0085	0.0087	0.0089	0.0091	0.0092	0.0095	0.0097	0.0101	—	—	
0.0075	0.0077	0.0078	0.0079	0.0081	0.0083	0.0085	0.0086	0.0088	0.0091	0.0093	0.0097	0.0101	—	16
0.0082	0.0084	0.0085	0.0086	0.0088	0.0090	0.0092	0.0093	0.0095	0.0098	0.0100	0.0104	0.0108	—	
0.0079	0.0081	0.0083	0.0084	0.0085	0.0087	0.0089	0.0091	0.0092	0.0095	0.0098	0.0102	0.0105	0.0108	14
0.0088	0.0090	0.0091	0.0093	0.0094	0.0096	0.0098	0.0100	0.0101	0.0104	0.0107	0.0111	0.0114	0.0117	
0.0085	0.0087	0.0088	0.0090	0.0091	0.0093	0.0095	0.0097	0.0098	0.0101	0.0103	0.0107	0.0111	0.0114	12
0.0094	0.0096	0.0098	0.0099	0.0100	0.0103	0.0104	0.0106	0.0108	0.0110	0.0113	0.0117	0.0120	0.0123	
0.0092	0.0094	0.0096	0.0097	0.0098	0.0100	0.0102	0.0104	0.0106	0.0108	0.0111	0.0115	0.0118	0.0121	10
0.0103	0.0105	0.0106	0.0107	0.0109	0.0111	0.0113	0.0114	0.0116	0.0119	0.0121	0.0125	0.0129	0.0132	
0.0103	0.0104	0.0106	0.0107	0.0108	0.0111	0.0113	0.0114	0.0116	0.0119	0.0121	0.0125	0.0129	0.0132	8
0.0114	0.0116	0.0118	0.0119	0.0120	0.0122	0.0124	0.0126	0.0128	0.0130	0.0133	0.0137	0.0140	0.0143	
—	0.0111	0.0113	0.0114	0.0115	0.0118	0.0119	0.0121	0.0123	0.0125	0.0128	0.0132	0.0135	0.0139	7
—	0.0124	0.0125	0.0127	0.0128	0.0130	0.0132	0.0134	0.0135	0.0138	0.0140	0.0145	0.0148	0.0151	
—	—	0.0121	0.0123	0.0124	0.0126	0.0128	0.0130	0.0131	0.0134	0.0137	0.0141	0.0144	0.0147	6
—	—	0.0135	0.0136	0.0138	0.0140	0.0142	0.0143	0.0145	0.0148	0.0150	0.0154	0.0158	0.0161	
—	—	—	—	0.0151	0.0154	0.0155	0.0157	0.0159	0.0162	0.0164	0.0168	0.0172	0.0175	4
—	—	—	—	0.0168	0.0170	0.0172	0.0174	0.0175	0.0178	0.0180	0.0185	0.0188	0.0191	

TABLE 24—*Class 2A, Pitch-Diameter Tolerances for External Threads*

THREADS PER INCH	LENGTHS OF ENGAGEMENT		PITCH-DIAMETER[a] TOLERANCES[b]								
	Number of pitches	Inches	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	3/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750
80	5 to 15	0.06 to 0.19	0.0019	0.0020	0.0021	0.0022	0.0023	—	—	—	—
	16 to 30	0.191 to 0.38	0.0022	0.0022	0.0023	0.0024	0.0025	—	—	—	—
72	5 to 15	0.07 to 0.21	0.0020	0.0021	0.0021	0.0023	0.0023	0.0025	—	—	—
	16 to 30	0.211 to 0.42	—	0.0023	0.0024	0.0025	0.0026	0.0027	—	—	—
64	5 to 15	0.08 to 0.23	0.0021	0.0022	0.0022	0.0024	0.0024	0.0026	0.0027	—	—
	16 to 30	0.231 to 0.46	—	0.0025	0.0025	0.0026	0.0027	0.0029	0.0030	—	—
56	5 to 15	0.09 to 0.27	—	0.0023	0.0024	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030
	16 to 30	0.271 to 0.54	—	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033
48	5 to 15	0.10 to 0.31	—	0.0025	0.0025	0.0026	0.0027	0.0029	0.0030	0.0031	0.0031
	16 to 30	0.311 to 0.62	—	—	0.0029	0.0030	0.0030	0.0032	0.0033	0.0034	0.0035
40	5 to 15	0.12 to 0.38	—	—	0.0027	0.0029	0.0029	0.0031	0.0032	0.0033	0.0034
	16 to 30	0.381 to 0.76	—	—	0.0031	0.0032	0.0033	0.0034	0.0035	0.0036	0.0037
36	5 to 15	0.14 to 0.42	—	—	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034	0.0035
	16 to 30	0.421 to 0.84	—	—	—	0.0034	0.0034	0.0036	0.0037	0.0038	0.0039
32	5 to 15	0.16 to 0.47	—	—	0.0030	0.0031	0.0032	0.0034	0.0035	0.0036	0.0036
	16 to 30	0.471 to 0.94	—	—	—	0.0035	0.0036	0.0038	0.0039	0.0040	0.0040
28	5 to 15	0.18 to 0.54	—	—	—	0.0033	0.0034	0.0036	0.0037	0.0038	0.0038
	16 to 30	0.541 to 1.08	—	—	—	0.0038	0.0038	0.0040	0.0041	0.0042	0.0043
24	5 to 15	0.21 to 0.62	—	—	—	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041
	16 to 30	0.621 to 1.24	—	—	—	—	0.0041	0.0043	0.0044	0.0045	0.0045
20	5 to 15	0.25 to 0.75	—	—	—	—	0.0040	0.0041	0.0042	0.0043	0.0044
	16 to 30	0.751 to 1.50	—	—	—	—	0.0045	0.0046	0.0047	0.0048	0.0049
18	5 to 15	0.28 to 0.83	—	—	—	—	—	0.0043	0.0044	0.0045	0.0046
	16 to 30	0.831 to 1.66	—	—	—	—	—	0.0048	0.0050	0.0050	0.0051
16	5 to 15	0.31 to 0.94	—	—	—	—	—	0.0046	0.0047	0.0048	0.0049
	16 to 30	0.941 to 1.88	—	—	—	—	—	0.0050	0.0051	0.0052	0.0053
14	5 to 15	0.36 to 1.07	—	—	—	—	—	—	0.0050	0.0051	0.0051
	16 to 30	1.071 to 2.14	—	—	—	—	—	—	0.0056	0.0057	0.0057
12	5 to 15	0.42 to 1.25	—	—	—	—	—	—	0.0054	0.0054	0.0055
	16 to 30	1.251 to 2.50	—	—	—	—	—	—	0.0060	0.0061	0.0062
10	5 to 15	0.50 to 1.50	—	—	—	—	—	—	—	—	0.0060
	16 to 30	1.501 to 3.00	—	—	—	—	—	—	—	—	0.0067
8	5 to 15	0.62 to 1.88	—	—	—	—	—	—	—	—	—
	16 to 30	1.881 to 3.76	—	—	—	—	—	—	—	—	—
7	5 to 15	0.71 to 2.14	—	—	—	—	—	—	—	—	—
	16 to 30	2.141 to 4.29	—	—	—	—	—	—	—	—	—
6	5 to 15	0.83 to 2.50	—	—	—	—	—	—	—	—	—
	16 to 30	2.501 to 5.00	—	—	—	—	—	—	—	—	—
4	5 to 15	1.25 to 3.75	—	—	—	—	—	—	—	—	—
	16 to 30	3.751 to 7.50	—	—	—	—	—	—	—	—	—

[a] British: Effective Diameter.
[b] Tolerances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

of Special Diameters, Pitches, and Lengths of Engagement—UNS and NS

PITCH-DIAMETER[a] TOLERANCES[b]														THREADS PER INCH
1 0.8751 to 1.1250	1¼ 1.1251 to 1.3750	1½ 1.3751 to 1.6250	1¾ 1.6251 to 1.8750	2 1.8751 to 2.2500	2½ 2.2501 to 2.7500	3 2.7501 to 3.2500	3½ 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	
—	—	—	—	NOTES										80
—	—	—	—	1. These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8N thread series.										
—	—	—	—	2. Formula:										72
—	—	—	—	Class 2A Tolerances = $0.0015\sqrt[3]{D} + 0.0015\sqrt{L_e} + 0.015\sqrt[3]{p^2}$										
—	—	—	—	Where D = basic major diameter										64
—	—	—	—	L_e = length of engagement										
—	—	—	—	p = pitch										
—	—	—	—	3. Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement from 16 to 30 pitches are based on lengths of 20 pitches. For lengths of engagement not tabulated, the formula in Note 2 should be applied.										56
—	—	—	—											
—	—	—	—	4. Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Note 2 should be applied.										48
—	—	—	—											
0.0035	—	—	—	5. Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement which are considered to be generally used. For other combinations encountered, see Limitations of Design, Appendix D.										40
0.0038	—	—	—											
0.0036	0.0037	0.0038	—	—	—	—	—	—	—	—	—	—	—	36
0.0040	0.0041	0.0042	—	—	—	—	—	—	—	—	—	—	—	
0.0038	0.0039	0.0040	0.0041	0.0042	0.0043	0.0044	—	—	—	—	—	—	—	32
0.0042	0.0043	0.0044	0.0045	0.0046	0.0047	0.0048	—	—	—	—	—	—	—	
0.0040	0.0041	0.0042	0.0043	0.0044	0.0045	0.0046	0.0048	0.0049	—	—	—	—	—	28
0.0044	0.0045	0.0046	0.0047	0.0048	0.0049	0.0051	0.0052	0.0053	—	—	—	—	—	
0.0042	0.0043	0.0044	0.0045	0.0046	0.0048	0.0049	0.0050	0.0051	0.0053	0.0054	—	—	—	24
0.0047	0.0048	0.0049	0.0050	0.0051	0.0052	0.0053	0.0054	0.0056	0.0057	0.0059	—	—	—	
0.0045	0.0047	0.0048	0.0048	0.0049	0.0051	0.0052	0.0053	0.0054	0.0056	0.0058	—	—	—	20
0.0050	0.0052	0.0053	0.0053	0.0054	0.0056	0.0057	0.0058	0.0059	0.0061	0.0063	—	—	—	
0.0047	0.0049	0.0050	0.0051	0.0051	0.0053	0.0054	0.0055	0.0056	0.0058	0.0060	0.0062	—	—	18
0.0053	0.0054	0.0055	0.0056	0.0057	0.0058	0.0059	0.0060	0.0061	0.0063	0.0065	0.0068	—	—	
0.0050	0.0051	0.0052	0.0053	0.0054	0.0055	0.0056	0.0058	0.0059	0.0061	0.0062	0.0065	0.0067	—	16
0.0055	0.0056	0.0057	0.0058	0.0058	0.0060	0.0061	0.0062	0.0063	0.0065	0.0067	0.0070	0.0072	—	
0.0053	0.0054	0.0055	0.0056	0.0057	0.0058	0.0059	0.0061	0.0062	0.0064	0.0065	0.0068	0.0070	0.0072	14
0.0059	0.0060	0.0061	0.0062	0.0063	0.0064	0.0065	0.0067	0.0068	0.0069	0.0071	0.0074	0.0076	0.0078	
0.0057	0.0058	0.0059	0.0060	0.0061	0.0062	0.0063	0.0064	0.0065	0.0067	0.0069	0.0072	0.0074	0.0076	12
0.0063	0.0064	0.0065	0.0066	0.0067	0.0068	0.0070	0.0071	0.0072	0.0074	0.0075	0.0078	0.0080	0.0082	
0.0062	0.0063	0.0064	0.0065	0.0065	0.0067	0.0068	0.0069	0.0070	0.0072	0.0074	0.0077	00.079	0.0081	10
0.0069	0.0070	0.0071	0.0072	0.0072	0.0074	0.0075	0.0076	0.0077	0.0079	0.0081	0.0084	0.0086	0.0088	
0.0068	0.0070	0.0071	0.0071	0.0072	0.0074	0.0075	0.0076	0.0077	0.0079	0.0081	0.0083	0.0086	0.0088	8
0.0076	0.0077	0.0078	0.0079	0.0080	0.0082	0.0083	0.0084	0.0085	0.0087	0.0088	0.0091	0.0094	0.0096	
—	0.0074	0.0075	0.0076	0.0077	0.0078	0.0080	0.0081	0.0082	0.0084	0.0085	0.0088	0.0090	0.0092	7
—	0.0082	0.0084	0.0084	0.0085	0.0087	0.0088	0.0089	0.0090	0.0092	0.0094	0.0096	0.0099	0.0101	
—	—	0.0081	0.0082	0.0083	0.0084	0.0085	0.0087	0.0088	0.0089	0.0091	0.0094	0.0096	0.0098	6
—	—	0.0090	0.0091	0.0092	0.0093	0.0094	0.0096	0.0097	0.0098	0.0100	0.0103	0.0105	0.0107	
—	—	—	—	0.0101	0.0102	0.0104	0.0105	0.0106	0.0108	0.0109	0.0112	0.0114	0.0116	4
—	—	—	—	0.0112	0.0113	0.0115	0.0116	0.0117	0.0119	0.0120	0.0123	0.0125	0.0127	

TABLE 25—*Class 3A, Pitch-Diameter Tolerances for External Threads*

THREADS PER INCH	LENGTHS OF ENGAGEMENT		PITCH-DIAMETER[a] TOLERANCES[b]								
	Number of pitches	Inches	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	3/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750
80	5 to 15	0.06 to 0.19	0.0014	0.0015	0.0015	0.0016	0.0017	—	—	—	—
	16 to 30	0.191 to 0.38	0.0016	0.0017	0.0017	0.0018	0.0019	—	—	—	—
72	5 to 15	0.07 to 0.21	0.0015	0.0016	0.0016	0.0017	0.0018	0.0019	—	—	—
	16 to 30	0.211 to 0.42	—	0.0018	0.0018	0.0019	0.0020	0.0021	—	—	—
64	5 to 15	0.08 to 0.23	0.0016	0.0016	0.0017	0.0018	0.0018	0.0019	0.0020	—	—
	16 to 30	0.231 to 0.46	—	0.0018	0.0019	0.0020	0.0020	0.0021	0.0022	—	—
56	5 to 15	0.09 to 0.27	—	0.0017	0.0018	0.0019	0.0019	0.0020	0.0021	0.0022	0.0022
	16 to 30	0.271 to 0.54	—	0.0020	0.0020	0.0021	0.0021	0.0023	0.0023	0.0024	0.0025
48	5 to 15	0.10 to 0.31	—	0.0019	0.0019	0.0020	0.0020	0.0022	0.0022	0.0023	0.0024
	16 to 30	0.311 to 0.62	—	—	0.0021	0.0022	0.0023	0.0024	0.0025	0.0025	0.0026
40	5 to 15	0.12 to 0.38	—	—	0.0021	0.0021	0.0022	0.0023	0.0024	0.0025	0.0025
	16 to 30	0.381 to 0.76	—	—	0.0023	0.0024	0.0025	0.0026	0.0027	0.0027	0.0028
36	5 to 15	0.14 to 0.42	—	—	0.0022	0.0022	0.0023	0.0024	0.0025	0.0026	0.0026
	16 to 30	0.421 to 0.84	—	—	—	0.0025	0.0026	0.0027	0.0028	0.0028	0.0029
32	5 to 15	0.16 to 0.47	—	—	0.0023	0.0024	0.0024	0.0025	0.0026	0.0027	0.0027
	16 to 30	0.471 to 0.94	—	—	—	0.0026	0.0027	0.0028	0.0029	0.0030	0.0030
28	5 to 15	0.18 to 0.54	—	—	—	0.0025	0.0026	0.0027	0.0028	0.0028	0.0029
	16 to 30	0.541 to 1.08	—	—	—	0.0028	0.0029	0.0030	0.0031	0.0031	0.0032
24	5 to 15	0.21 to 0.62	—	—	—	0.0027	0.0028	0.0029	0.0029	0.0030	0.0031
	16 to 30	0.621 to 1.24	—	—	—	—	0.0031	0.0032	0.0033	0.0033	0.0034
20	5 to 15	0.25 to 0.75	—	—	—	—	0.0030	0.0031	0.0032	0.0032	0.0033
	16 to 30	0.751 to 1.50	—	—	—	—	0.0034	0.0035	0.0035	0.0036	0.0037
18	5 to 15	0.28 to 0.83	—	—	—	—	—	0.0032	0.0033	0.0034	0.0035
	16 to 30	0.831 to 1.66	—	—	—	—	—	0.0036	0.0037	0.0038	0.0038
16	5 to 15	0.31 to 0.94	—	—	—	—	—	0.0034	0.0035	0.0036	0.0036
	16 to 30	0.941 to 1.88	—	—	—	—	—	0.0038	0.0039	0.0039	0.0040
14	5 to 15	0.36 to 1.07	—	—	—	—	—	—	0.0037	0.0038	0.0039
	16 to 30	1.071 to 2.14	—	—	—	—	—	—	0.0042	0.0042	0.0043
12	5 to 15	0.42 to 1.25	—	—	—	—	—	—	0.0040	0.0041	0.0041
	16 to 30	1.251 to 2.50	—	—	—	—	—	—	0.0045	0.0046	0.0046
10	5 to 15	0.50 to 1.50	—	—	—	—	—	—	—	—	0.0045
	16 to 30	1.501 to 3.00	—	—	—	—	—	—	—	—	0.0050
8	5 to 15	0.62 to 1.88	—	—	—	—	—	—	—	—	—
	16 to 30	1.881 to 3.76	—	—	—	—	—	—	—	—	—
7	5 to 15	0.71 to 2.14	—	—	—	—	—	—	—	—	—
	16 to 30	2.141 to 4.29	—	—	—	—	—	—	—	—	—
6	5 to 15	0.83 to 2.50	—	—	—	—	—	—	—	—	—
	16 to 30	2.501 to 5.00	—	—	—	—	—	—	—	—	—
4	5 to 15	1.25 to 3.75	—	—	—	—	—	—	—	—	—
	16 to 30	3.751 to 7.50	—	—	—	—	—	—	—	—	—

[a] British: Effective Diameter.
[b] Tolerances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

of Special Diameters, Pitches, and Lengths of Engagement—UNS and NS

PITCH-DIAMETER[a] TOLERANCES[b]													THREADS PER INCH
1 0.8751 to 1.1250	1¼ 1.1251 to 1.3750	1½ 1.3751 to 1.6250	1¾ 1.6251 to 1.8750	2 1.8751 to 2.2500	2½ 2.2501 to 2.7500	3 2.7501 to 3.2500	3½ 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	
—	—	—	NOTES											80
—	—	—	1. These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8N thread series.											
—	—	—	2. Formula:											72
—	—	—	Class 3A tolerances for external threads are determined by multiplying Class 2A tolerances (computed to six decimal places) by 0.750. See Note 2, Table 24, for formula for Class 2A tolerances.											
—	—	—	3. Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement from 16 to 30 pitches are based on lengths of 20 pitches. For lengths of engagement not tabulated, the formula in Note 2 should be applied.											64
—	—	—	4. Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Note 2 should be applied.											56
—	—	—	5. Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement which are considered to be generally used. For other combinations encountered, see Limitations of Design, Appendix D.											48
0.0026	—	—												40
0.0029	—	—												
0.0027	0.0028	0.0029	—	—	—	—	—	—	—	—	—	—	—	36
0.0030	0.0031	0.0032	—	—	—	—	—	—	—	—	—	—	—	
0.0028	0.0029	0.0030	0.0031	0.0031	0.0032	0.0033	—	—	—	—	—	—	—	32
0.0031	0.0032	0.0033	0.0034	0.0034	0.0035	0.0036	—	—	—	—	—	—	—	
0.0030	0.0031	0.0031	0.0032	0.0033	0.0034	0.0035	0.0036	0.0036	—	—	—	—	—	28
0.0033	0.0034	0.0035	0.0035	0.0036	0.0037	0.0038	0.0039	0.0040	—	—	—	—	—	
0.0032	0.0033	0.0033	0.0034	0.0035	0.0036	0.0037	0.0037	0.0038	0.0040	0.0041	—	—	—	24
0.0035	0.0036	0.0037	0.0037	0.0038	0.0039	0.0040	0.0041	0.0042	0.0043	0.0044	—	—	—	
0.0034	0.0035	0.0036	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0042	0.0043	—	—	—	20
0.0038	0.0039	0.0039	0.0040	0.0041	0.0042	0.0043	0.0044	0.0044	0.0046	0.0047	—	—	—	
0.0036	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0041	0.0042	0.0044	0.0045	0.0047	—	—	18
0.0039	0.0040	0.0041	0.0042	0.0042	0.0044	0.0044	0.0045	0.0046	0.0047	0.0049	0.0051	—	—	
0.0037	0.0038	0.0039	0.0040	0.0040	0.0041	0.0042	0.0043	0.0044	0.0045	0.0047	0.0049	0.0050	—	16
0.0041	0.0042	0.0043	0.0043	0.0044	0.0045	0.0046	0.0047	0.0048	0.0049	0.0050	0.0052	0.0054	—	
0.0040	0.0041	0.0041	0.0042	0.0043	0.0044	0.0045	0.0045	0.0046	0.0048	0.0049	0.0051	0.0053	0.0054	14
0.0044	0.0045	0.0046	0.0046	0.0047	0.0048	0.0049	0.0050	0.0051	0.0052	0.0053	0.0055	0.0057	0.0059	
0.0042	0.0043	0.0044	0.0045	0.0045	0.0046	0.0047	0.0048	0.0049	0.0050	0.0052	0.0054	0.0055	0.0057	12
0.0047	0.0048	0.0049	0.0050	0.0050	0.0051	0.0052	0.0053	0.0054	0.0055	0.0056	0.0058	0.0060	0.0062	
0.0046	0.0047	0.0048	0.0048	0.0049	0.0050	0.0051	0.0052	0.0053	0.0054	0.0055	0.0057	0.0059	0.0061	10
0.0051	0.0052	0.0053	0.0054	0.0054	0.0055	0.0056	0.0057	0.0058	0.0059	0.0061	0.0063	0.0064	0.0066	
0.0051	0.0052	0.0053	0.0054	0.0054	0.0055	0.0056	0.0057	0.0058	0.0059	0.0061	0.0063	0.0064	0.0066	8
0.0057	0.0058	0.0059	0.0059	0.0060	0.0061	0.0062	0.0063	0.0064	0.0065	0.0066	0.0068	0.0070	0.0072	
—	0.0056	0.0056	0.0057	0.0058	0.0059	0.0060	0.0061	0.0061	0.0063	0.0064	0.0066	0.0068	0.0069	7
—	0.0062	0.0063	0.0063	0.0064	0.0065	0.0066	0.0067	0.0068	0.0069	0.0070	0.0072	0.0074	0.0076	
—	—	0.0061	0.0061	0.0062	0.0063	0.0064	0.0065	0.0066	0.0067	0.0068	0.0070	0.0072	0.0074	6
—	—	0.0067	0.0068	0.0069	0.0070	0.0071	0.0072	0.0072	0.0074	0.0075	0.0077	0.0079	0.0080	
—	—	—	—	0.0076	0.0077	0.0078	0.0079	0.0079	0.0081	0.0082	0.0084	0.0086	0.0087	4
—	—	—	—	0.0084	0.0085	0.0086	0.0087	0.0088	0.0089	0.0090	0.0092	0.0094	0.0096	

TABLE 26—*Class 1B, Pitch-Diameter Tolerances for External Threads of*

THREADS PER INCH	LENGTHS OF ENGAGEMENT		PITCH-DIAMETER[a] TOLERANCES[b]								
	Number of pitches	Inches	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	3/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750
80	5 to 15	0.06 to 0.19	—	—	—	—	—	—	—	—	—
	16 to 30	0.191 to 0.38	—	—	—	—	—	—	—	—	—
72	5 to 15	0.07 to 0.21	—	—	—	—	—	—	—	—	—
	16 to 30	0.211 to 0.42	—	—	—	—	—	—	—	—	—
64	5 to 15	0.08 to 0.23	—	—	—	—	—	—	—	—	—
	16 to 30	0.231 to 0.46	—	—	—	—	—	—	—	—	—
56	5 to 15	0.09 to 0.27	—	—	—	—	—	—	—	—	—
	16 to 30	0.271 to 0.54	—	—	—	—	—	—	—	—	—
48	5 to 15	0.10 to 0.31	—	—	—	—	—	—	—	—	—
	16 to 30	0.311 to 0.62	—	—	—	—	—	—	—	—	—
40	5 to 15	0.12 to 0.38	—	—	0.0054	0.0056	0.0057	0.0060	0.0062	0.0064	0.0065
	16 to 30	0.381 to 0.76	—	—	0.0060	0.0062	0.0064	0.0067	0.0069	0.0071	0.0072
36	5 to 15	0.14 to 0.42	—	—	0.0056	0.0058	0.0060	0.0063	0.0065	0.0066	0.0068
	16 to 30	0.421 to 0.84	—	—	—	0.0065	0.0067	0.0070	0.0072	0.0074	0.0075
32	5 to 15	0.16 to 0.47	—	—	0.0059	0.0061	0.0063	0.0066	0.0068	0.0070	0.0071
	16 to 30	0.471 to 0.94	—	—	—	0.0069	0.0071	0.0073	0.0075	0.0077	0.0079
28	5 to 15	0.18 to 0.54	—	—	—	0.0065	0.0067	0.0069	0.0072	0.0073	0.0075
	16 to 30	0.541 to 1.08	—	—	—	0.0073	0.0075	0.0078	0.0080	0.0081	0.0083
24	5 to 15	0.21 to 0.62	—	—	—	0.0070	0.0072	0.0074	0.0076	0.0078	0.0080
	16 to 30	0.621 to 1.24	—	—	—	—	0.0080	0.0083	0.0085	0.0087	0.0088
20	5 to 15	0.25 to 0.75	—	—	—	—	0.0078	0.0080	0.0083	0.0084	0.0086
	16 to 30	0.751 to 1.50	—	—	—	—	0.0087	0.0090	0.0092	0.0094	0.0096
18	5 to 15	0.28 to 0.83	—	—	—	—	—	0.0084	0.0087	0.0088	0.0090
	16 to 30	0.831 to 1.66	—	—	—	—	—	0.0095	0.0097	0.0098	0.0100
16	5 to 15	0.31 to 0.94	—	—	—	—	—	0.0089	0.0091	0.0093	0.0095
	16 to 30	0.941 to 1.88	—	—	—	—	—	0.0098	0.0100	0.0102	0.0104
14	5 to 15	0.36 to 1.07	—	—	—	—	—	—	0.0097	0.0099	0.0100
	16 to 30	1.071 to 2.14	—	—	—	—	—	—	0.0109	0.0110	0.0112
12	5 to 15	0.42 to 1.25	—	—	—	—	—	—	0.0104	0.0106	0.0108
	16 to 30	1.251 to 2.50	—	—	—	—	—	—	0.0117	0.0119	0.0120
10	5 to 15	0.50 to 1.50	—	—	—	—	—	—	—	—	0.0117
	16 to 30	1.501 to 3.00	—	—	—	—	—	—	—	—	0.0131
8	5 to 15	0.62 to 1.88	—	—	—	—	—	—	—	—	—
	16 to 30	1.881 to 3.76	—	—	—	—	—	—	—	—	—
7	5 to 15	0.71 to 2.14	—	—	—	—	—	—	—	—	—
	16 to 30	2.141 to 4.29	—	—	—	—	—	—	—	—	—
6	5 to 15	0.83 to 2.50	—	—	—	—	—	—	—	—	—
	16 to 30	2.501 to 5.00	—	—	—	—	—	—	—	—	—
4	5 to 15	1.25 to 3.75	—	—	—	—	—	—	—	—	—
	16 to 30	3.751 to 7.50	—	—	—	—	—	—	—	—	—

[a] British: Effective Diameter.
[b] Tolerances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

Special Diameters, Pitches, and Lengths of Engagement—UNS and NS

PITCH-DIAMETER[a] TOLERANCES[b]													THREADS PER INCH
1 0.8751 to 1.1250	1 ¼ 1.1251 to 1.3750	1 ½ 1.3751 to 1.6250	1 ¾ 1.6251 to 1.8750	2 1.8751 to 2.2500	2 ½ 2.2501 to 2.7500	3 2.7501 to 3.2500	3 ½ 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	
—	—	—	NOTES											80
—	—	—	1. These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8N thread series.											
—	—	—	2. Formula: Class 1B tolerances for internal threads are 1.5 times Class 2B tolerances and are determined by multiplying Class 2A tolerances (computed to six decimal places) by 1.950. See Note 2, Table 24, for formula for Class 2A tolerances.											72
—	—	—	3. Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement from 16 to 30 pitches are based on lengths of 20 pitches. For lengths of engagement not tabulated, the formula in Note 2 should be applied.											64
—	—	—	4. Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Note 2 should be applied.											56
—	—	—	5. Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement which are considered to be generally used. For other combinations encountered, see Limitations of Design, Appendix D.											48
0.0068	—	—												40
0.0075	—	—												
0.0071	0.0073	0.0075	—	—	—	—	—	—	—	—	—	—	—	36
0.0078	0.0080	0.0082	—	—	—	—	—	—	—	—	—	—	—	
0.0074	0.0076	0.0078	0.0080	0.0081	0.0084	0.0087	—	—	—	—	—	—	—	32
0.0081	0.0084	0.0086	0.0087	0.0089	0.0092	0.0094	—	—	—	—	—	—	—	
0.0078	0.0080	0.0082	0.0084	0.0085	0.0088	0.0090	0.0093	0.0095	—	—	—	—	—	28
0.0086	0.0088	0.0090	0.0092	0.0093	0.0096	0.0099	0.0101	0.0103	—	—	—	—	—	
0.0082	0.0085	0.0087	0.0088	0.0090	0.0093	0.0095	0.0097	0.0100	0.0103	0.0106	—	—	—	24
0.0091	0.0093	0.0095	0.0097	0.0099	0.0102	0.0104	0.0106	0.0108	0.0112	0.0115	—	—	—	
0.0089	0.0091	0.0093	0.0095	0.0096	0.0099	0.0101	0.0104	0.0106	0.0109	0.0112	—	—	—	20
0.0098	0.0100	0.0102	0.0104	0.0106	0.0109	0.0111	0.0113	0.0115	0.0119	0.0122	—	—	—	
0.0093	0.0095	0.0097	0.0099	0.0100	0.0103	0.0105	0.0108	0.0110	0.0113	0.0116	0.0122	—	—	18
0.0103	0.0105	0.0107	0.0109	0.0110	0.0113	0.0116	0.0118	0.0120	0.0123	0.0127	0.0132	—	—	
0.0097	0.0100	0.0101	0.0103	0.0105	0.0108	0.0110	0.0112	0.0114	0.0118	0.0121	0.0126	0.0131	—	16
0.0106	0.0109	0.0111	0.0112	0.0114	0.0117	0.0119	0.0121	0.0124	0.0127	0.0130	0.0136	0.0140	—	
0.0103	0.0105	0.0107	0.0109	0.0111	0.0114	0.0116	0.0118	0.0120	0.0124	0.0127	0.0132	0.0137	0.0141	14
0.0115	0.0117	0.0119	0.0121	0.0122	0.0125	0.0127	0.0130	0.0132	0.0135	0.0138	0.0144	0.0148	0.0152	
0.0110	0.0113	0.0115	0.0116	0.0118	0.0121	0.0123	0.0126	0.0128	0.0131	0.0134	0.0140	0.0144	0.0148	12
0.0123	0.0125	0.0127	0.0129	0.0130	0.0133	0.0136	0.0138	0.0140	0.0144	0.0147	0.0152	0.0157	0.0161	
0.0120	0.0122	0.0124	0.0126	0.0128	0.0130	0.0133	0.0135	0.0137	0.0141	0.0144	0.0149	0.0154	0.0158	10
0.0134	0.0136	0.0138	0.0140	0.0141	0.0144	0.0147	0.0149	0.0151	0.0154	0.0158	0.0163	0.0167	0.0171	
0.0133	0.0136	0.0138	0.0139	0.0141	0.0144	0.0146	0.0149	0.0151	0.0154	0.0157	0.0163	0.0167	0.0171	8
0.0149	0.0151	0.0153	0.0155	0.0156	0.0159	0.0162	0.0164	0.0166	0.0169	0.0173	0.0178	0.0182	0.0186	
—	0.0145	0.0147	0.0148	0.0150	0.0153	0.0155	0.0158	0.0160	0.0163	0.0166	0.0172	0.0176	0.0180	7
—	0.0161	0.0163	0.0165	0.0166	0.0169	0.0172	0.0174	0.0176	0.0179	0.0183	0.0188	0.0192	0.0196	
—	—	0.0158	0.0160	0.0161	0.0164	0.0167	0.0169	0.0171	0.0174	0.0178	0.0183	0.0187	0.0191	6
—	—	0.0175	0.0177	0.0179	0.0182	0.0184	0.0186	0.0188	0.0192	0.0195	0.0200	0.0205	0.0209	
—	—	—	—	0.0197	0.0200	0.0202	0.0204	0.0206	0.0210	0.0213	0.0218	0.0223	0.0227	4
—	—	—	—	0.0218	0.0221	0.0224	0.0226	0.0228	0.0232	0.0235	0.0240	0.0245	0.0248	

TABLE 27—*Class 2B, Pitch-Diameter Tolerances for Internal Threads of*

THREADS PER INCH	LENGTHS OF ENGAGEMENT		PITCH-DIAMETER[a] TOLERANCES[b]								
	Number of pitches	Inches	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	3/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750
80	5 to 15	0.06 to 0.19	0.0025	0.0026	0.0027	0.0028	0.0029	—	—	—	—
	16 to 30	0.191 to 0.38	0.0028	0.0029	0.0030	0.0031	0.0033	—	—	—	—
72	5 to 15	0.07 to 0.21	0.0026	0.0027	0.0028	0.0029	0.0030	0.0032	—	—	—
	16 to 30	0.211 to 0.42	—	0.0030	0.0031	0.0033	0.0034	0.0036	—	—	—
64	5 to 15	0.08 to 0.23	0.0027	0.0028	0.0029	0.0031	0.0032	0.0034	0.0035	—	—
	16 to 30	0.231 to 0.46	—	0.0032	0.0033	0.0034	0.0035	0.0037	0.0039	—	—
56	5 to 15	0.09 to 0.27	—	0.0030	0.0031	0.0032	0.0033	0.0035	0.0037	0.0038	0.0039
	16 to 30	0.271 to 0.54	—	0.0034	0.0035	0.0036	0.0037	0.0039	0.0040	0.0042	0.0043
48	5 to 15	0.10 to 0.31	—	0.0032	0.0033	0.0034	0.0036	0.0037	0.0039	0.0040	0.0041
	16 to 30	0.311 to 0.62	—	—	0.0037	0.0039	0.0040	0.0041	0.0043	0.0044	0.0045
40	5 to 15	0.12 to 0.38	—	—	0.0036	0.0037	0.0038	0.0040	0.0041	0.0043	0.0044
	16 to 30	0.381 to 0.76	—	—	0.0040	0.0042	0.0043	0.0045	0.0046	0.0047	0.0048
36	5 to 15	0.14 to 0.42	—	—	0.0037	0.0039	0.0040	0.0042	0.0043	0.0044	0.0045
	16 to 30	0.421 to 0.84	—	—	—	0.0044	0.0045	0.0046	0.0048	0.0049	0.0050
32	5 to 15	0.16 to 0.47	—	—	0.0039	0.0041	0.0042	0.0044	0.0045	0.0046	0.0047
	16 to 30	0.471 to 0.94	—	—	—	0.0046	0.0047	0.0049	0.0050	0.0051	0.0052
28	5 to 15	0.18 to 0.54	—	—	—	0.0043	0.0044	0.0046	0.0048	0.0049	0.0050
	16 to 30	0.541 to 1.08	—	—	—	0.0049	0.0050	0.0052	0.0053	0.0054	0.0055
24	5 to 15	0.21 to 0.62	—	—	—	0.0047	0.0048	0.0049	0.0051	0.0052	0.0053
	16 to 30	0.621 to 1.24	—	—	—	—	0.0054	0.0055	0.0057	0.0058	0.0059
20	5 to 15	0.25 to 0.75	—	—	—	—	0.0052	0.0054	0.0055	0.0056	0.0057
	16 to 30	0.751 to 1.50	—	—	—	—	0.0058	0.0060	0.0061	0.0063	0.0064
18	5 to 15	0.28 to 0.83	—	—	—	—	—	0.0056	0.0058	0.0059	0.0060
	16 to 30	0.831 to 1.66	—	—	—	—	—	0.0063	0.0064	0.0066	0.0067
16	5 to 15	0.31 to 0.94	—	—	—	—	—	0.0059	0.0061	0.0062	0.0063
	16 to 30	0.941 to 1.88	—	—	—	—	—	0.0065	0.0067	0.0068	0.0069
14	5 to 15	0.36 to 1.07	—	—	—	—	—	—	0.0065	0.0066	0.0067
	16 to 30	1.071 to 2.14	—	—	—	—	—	—	0.0072	0.0074	0.0075
12	5 to 15	0.42 to 1.25	—	—	—	—	—	—	0.0070	0.0071	0.0072
	16 to 30	1.251 to 2.50	—	—	—	—	—	—	0.0078	0.0079	0.0080
10	5 to 15	0.50 to 1.50	—	—	—	—	—	—	—	—	0.0078
	16 to 30	1.501 to 3.00	—	—	—	—	—	—	—	—	0.0087
8	5 to 15	0.62 to 1.88	—	—	—	—	—	—	—	—	—
	16 to 30	1.881 to 3.76	—	—	—	—	—	—	—	—	—
7	5 to 15	0.71 to 2.14	—	—	—	—	—	—	—	—	—
	16 to 30	2.141 to 4.29	—	—	—	—	—	—	—	—	—
6	5 to 15	0.83 to 2.50	—	—	—	—	—	—	—	—	—
	16 to 30	2.501 to 5.00	—	—	—	—	—	—	—	—	—
4	5 to 15	1.25 to 3.75	—	—	—	—	—	—	—	—	—
	16 to 30	3.751 to 7.50	—	—	—	—	—	—	—	—	—

[a] British: Effective Diameter.
[b] Tolerances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

Special Diameters, Pitches, and Lengths of Engagement—UNS and NS

PITCH-DIAMETER[a] TOLERANCES[b]														
1 0.8751 to 1.1250	1 ¼ 1.1251 to 1.3750	1 ½ 1.3751 to 1.6250	1 ¾ 1.6251 to 1.8750	2 1.8751 to 2.2500	2 ½ 2.2501 to 2.7500	3 2.7501 to 3.2500	3 ½ 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	THREADS PER INCH
—	—	—	—											80
—	—	—	—											
—	—	—	—											72
—	—	—	—											
—	—	—	—											64
—	—	—	—											
—	—	—	—											56
—	—	—	—											
—	—	—	—											48
—	—	—	—											
0.0045	—	—	—											40
0.0050	—	—	—											
0.0047	0.0049	0.0050	—	—	—	—	—	—	—	—	—	—	—	36
0.0052	0.0053	0.0055	—	—	—	—	—	—	—	—	—	—	—	
0.0049	0.0051	0.0052	0.0053	0.0054	0.0056	0.0058	—	—	—	—	—	—	—	32
0.0054	0.0056	0.0057	0.0058	0.0059	0.0061	0.0063	—	—	—	—	—	—	—	
0.0052	0.0053	0.0055	0.0056	0.0057	0.0059	0.0060	0.0062	0.0063	—	—	—	—	—	28
0.0057	0.0059	0.0060	0.0061	0.0062	0.0064	0.0066	0.0067	0.0069	—	—	—	—	—	
0.0055	0.0056	0.0058	0.0059	0.0060	0.0062	0.0064	0.0065	0.0066	0.0069	0.0071	—	—	—	24
0.0061	0.0062	0.0064	0.0065	0.0066	0.0068	0.0069	0.0071	0.0072	0.0075	0.0077	—	—	—	
0.0059	0.0061	0.0062	0.0063	0.0064	0.0066	0.0068	0.0069	0.0070	0.0073	0.0075	—	—	—	20
0.0065	0.0067	0.0068	0.0069	0.0071	0.0072	0.0074	0.0076	0.0077	0.0079	0.0081	—	—	—	
0.0062	0.0063	0.0065	0.0066	0.0067	0.0069	0.0070	0.0072	0.0073	0.0076	0.0078	0.0081	—	—	18
0.0068	0.0070	0.0071	0.0072	0.0074	0.0075	0.0077	0.0079	0.0080	0.0082	0.0084	0.0088	—	—	
0.0065	0.0066	0.0068	0.0069	0.0070	0.0072	0.0073	0.0075	0.0076	0.0079	0.0081	0.0084	0.0087	—	16
0.0071	0.0072	0.0074	0.0075	0.0076	0.0078	0.0080	0.0081	0.0082	0.0085	0.0087	0.0090	0.0093	—	
0.0069	0.0070	0.0072	0.0073	0.0074	0.0076	0.0077	0.0079	0.0080	0.0083	0.0085	0.0088	0.0091	0.0094	14
0.0076	0.0078	0.0079	0.0080	0.0081	0.0083	0.0085	0.0086	0.0088	0.0090	0.0092	0.0096	0.0099	0.0102	
0.0074	0.0075	0.0076	0.0078	0.0079	0.0081	0.0082	0.0084	0.0085	0.0087	0.0090	0.0093	0.0096	0.0099	12
0.0082	0.0083	0.0085	0.0086	0.0087	0.0089	0.0090	0.0092	0.0093	0.0096	0.0098	0.0101	0.0104	0.0107	
0.0080	0.0082	0.0083	0.0084	0.0085	0.0087	0.0089	0.0090	0.0091	0.0094	0.0096	0.0100	0.0103	0.0105	10
0.0089	0.0091	0.0092	0.0093	0.0094	0.0096	0.0098	0.0099	0.0101	0.0103	0.0105	0.0109	0.0112	0.0114	
0.0089	0.0090	0.0092	0.0093	0.0094	0.0096	0.0098	0.0099	0.0100	0.0103	0.0105	0.0108	0.0111	0.0114	8
0.0099	0.0101	0.0102	0.0103	0.0104	0.0106	0.0108	0.0109	0.0111	0.0113	0.0115	0.0119	0.0122	0.0124	
—	0.0096	0.0098	0.0099	0.0100	0.0102	0.0104	0.0105	0.0106	0.0109	0.0111	0.0114	0.0117	0.0120	7
—	0.0107	0.0109	0.0110	0.0111	0.0113	0.0114	0.0116	0.0117	0.0120	0.0122	0.0125	0.0128	0.0131	
—	—	0.0105	0.0106	0.0108	0.0109	0.0111	0.0113	0.0114	0.0116	0.0118	0.0122	0.0125	0.0128	6
—	—	0.0117	0.0118	0.0119	0.0121	0.0123	0.0124	0.0126	0.0128	0.0130	0.0134	0.0137	0.0139	
—	—	—	—	0.0131	0.0133	0.0135	0.0136	0.0138	0.0140	0.0142	0.0146	0.0149	0.0151	4
—	—	—	—	0.0146	0.0147	0.0149	0.0151	0.0152	0.0154	0.0156	0.0160	0.0163	0.0166	

NOTES

1. These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8N thread series.
2. Formula:
   Class 2B tolerances are determined by multiplying Class 2A tolerances (computed to six decimal places) by 1.300. See Note 2, Table 24, for formula for Class 2A tolerances.
3. Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement from 16 to 30 pitches are based on lengths of 20 pitches. For lengths of engagement not tabulated, the formula in Note 2 should be applied.
4. Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Note 2 should be applied.
5. Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement which are considered to be generally used. For other combinations encountered, see Limitations of Design, Appendix D.

TABLE 28—*Class 3B, Pitch-Diameter Tolerances for Internal Threads*

THREADS PER INCH	LENGTHS OF ENGAGEMENT		PITCH-DIAMETER[a] TOLERANCES[b]								
	Number of pitches	Inches	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	3/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750
80	5 to 15	0.06 to 0.19	0.0019	0.0019	0.0020	0.0021	0.0022	—	—	—	—
	16 to 30	0.191 to 0.38	0.0021	0.0022	0.0023	0.0024	0.0024	—	—	—	—
72	5 to 15	0.07 to 0.21	0.0019	0.0020	0.0021	0.0022	0.0023	0.0024	—	—	—
	16 to 30	0.211 to 0.42	—	0.0023	0.0023	0.0025	0.0025	0.0027	—	—	—
64	5 to 15	0.08 to 0.23	0.0020	0.0021	0.0022	0.0023	0.0024	0.0025	0.0026	—	—
	16 to 30	0.231 to 0.46	—	0.0024	0.0025	0.0026	0.0027	0.0028	0.0029	—	—
56	5 to 15	0.09 to 0.27	—	0.0023	0.0023	0.0024	0.0025	0.0026	0.0027	0.0028	0.0029
	16 to 30	0.271 to 0.54	—	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032
48	5 to 15	0.10 to 0.31	—	0.0024	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031
	16 to 30	0.311 to 0.62	—	—	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034
40	5 to 15	0.12 to 0.38	—	—	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033
	16 to 30	0.381 to 0.76	—	—	0.0030	0.0031	0.0032	0.0033	0.0034	0.0035	0.0036
36	5 to 15	0.14 to 0.42	—	—	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034
	16 to 30	0.421 to 0.84	—	—	—	0.0033	0.0034	0.0035	0.0036	0.0037	0.0038
32	5 to 15	0.16 to 0.47	—	—	0.0030	0.0031	0.0031	0.0033	0.0034	0.0035	0.0036
	16 to 30	0.471 to 0.94	—	—	—	0.0034	0.0035	0.0037	0.0038	0.0039	0.0039
28	5 to 15	0.18 to 0.54	—	—	—	0.0033	0.0033	0.0035	0.0036	0.0037	0.0037
	16 to 30	0.541 to 1.08	—	—	—	0.0037	0.0037	0.0039	0.0040	0.0041	0.0042
24	5 to 15	0.21 to 0.62	—	—	—	0.0035	0.0036	0.0037	0.0038	0.0039	0.0040
	16 to 30	0.621 to 1.24	—	—	—	—	0.0040	0.0041	0.0043	0.0043	0.0044
20	5 to 15	0.25 to 0.75	—	—	—	—	0.0039	0.0040	0.0041	0.0042	0.0043
	16 to 30	0.751 to 1.50	—	—	—	—	0.0044	0.0045	0.0046	0.0047	0.0048
18	5 to 15	0.28 to 0.83	—	—	—	—	—	0.0042	0.0043	0.0044	0.0045
	16 to 30	0.831 to 1.66	—	—	—	—	—	0.0047	0.0048	0.0049	0.0050
16	5 to 15	0.31 to 0.94	—	—	—	—	—	0.0045	0.0046	0.0046	0.0047
	16 to 30	0.941 to 1.88	—	—	—	—	—	0.0049	0.0050	0.0051	0.0052
14	5 to 15	0.36 to 1.07	—	—	—	—	—	—	0.0049	0.0049	0.0050
	16 to 30	1.071 to 2.14	—	—	—	—	—	—	0.0054	0.0055	0.0056
12	5 to 15	0.42 to 1.25	—	—	—	—	—	—	0.0052	0.0053	0.0054
	16 to 30	1.251 to 2.50	—	—	—	—	—	—	0.0058	0.0059	0.0060
10	5 to 15	0.50 to 1.50	—	—	—	—	—	—	—	—	0.0059
	16 to 30	1.501 to 3.00	—	—	—	—	—	—	—	—	0.0065
8	5 to 15	0.62 to 1.88	—	—	—	—	—	—	—	—	—
	16 to 30	1.881 to 3.76	—	—	—	—	—	—	—	—	—
7	5 to 15	0.71 to 2.14	—	—	—	—	—	—	—	—	—
	16 to 30	2.141 to 4.29	—	—	—	—	—	—	—	—	—
6	5 to 15	0.83 to 2.50	—	—	—	—	—	—	—	—	—
	16 to 30	2.501 to 5.00	—	—	—	—	—	—	—	—	—
4	5 to 15	1.25 to 3.75	—	—	—	—	—	—	—	—	—
	16 to 30	3.751 to 7.50	—	—	—	—	—	—	—	—	—

[a] British: Effective Diameter.
[b] Tolerances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

of Special Diameters, Pitches, and Lengths of Engagement—UNS and NS

PITCH-DIAMETER[a] TOLERANCES[b]

1 0.8751 to 1.1250	1¼ 1.1251 to 1.3750	1½ 1.3751 to 1.6250	1¾ 1.6251 to 1.8750	2 1.8751 to 2.2500	2½ 2.2501 to 2.7500	3 2.7501 to 3.2500	3½ 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	THREADS PER INCH
—	—	—												80
—	—	—												
—	—	—												72
—	—	—												
—	—	—												64
—	—	—												
—	—	—												56
—	—	—												
—	—	—												48
0.0034	—	—												
0.0037	—	—												40
0.0035	0.0036	0.0037	—	—	—	—	—	—	—	—	—	—	—	
0.0039	0.0040	0.0041	—	—	—	—	—	—	—	—	—	—	—	36
0.0037	0.0038	0.0039	0.0040	0.0041	0.0042	0.0043	—	—	—	—	—	—	—	
0.0041	0.0042	0.0043	0.0044	0.0044	0.0046	0.0047	—	—	—	—	—	—	—	32
0.0039	0.0040	0.0041	0.0042	0.0043	0.0044	0.0045	0.0046	0.0047	—	—	—	—	—	
0.0043	0.0044	0.0045	0.0046	0.0047	0.0048	0.0049	0.0050	0.0051	—	—	—	—	—	28
0.0041	0.0042	0.0043	0.0044	0.0045	0.0046	0.0048	0.0049	0.0050	0.0052	0.0053	—	—	—	
0.0046	0.0047	0.0048	0.0049	0.0049	0.0051	0.0052	0.0053	0.0054	0.0056	0.0058	—	—	—	24
0.0044	0.0045	0.0046	0.0047	0.0048	0.0050	0.0051	0.0052	0.0053	0.0055	0.0056	—	—	—	
0.0049	0.0050	0.0051	0.0052	0.0053	0.0054	0.0056	0.0057	0.0058	0.0059	0.0061	—	—	—	20
0.0046	0.0047	0.0048	0.0049	0.0050	0.0051	0.0053	0.0054	0.0055	0.0057	0.0058	0.0061	—	—	
0.0051	0.0052	0.0053	0.0054	0.0055	0.0057	0.0058	0.0059	0.0060	0.0062	0.0063	0.0066	—	—	18
0.0049	0.0050	0.0051	0.0052	0.0052	0.0054	0.0055	0.0056	0.0057	0.0059	0.0061	0.0063	0.0066	—	
0.0053	0.0054	0.0055	0.0056	0.0057	0.0058	0.0060	0.0061	0.0062	0.0064	0.0065	0.0068	0.0070	—	16
0.0052	0.0053	0.0054	0.0055	0.0055	0.0057	0.0058	0.0059	0.0060	0.0062	0.0063	0.0066	0.0068	0.0070	
0.0057	0.0058	0.0059	0.0060	0.0061	0.0063	0.0064	0.0065	0.0066	0.0068	0.0069	0.0072	0.0074	0.0076	14
0.0055	0.0056	0.0057	0.0058	0.0059	0.0060	0.0062	0.0063	0.0064	0.0066	0.0067	0.0070	0.0072	0.0074	
0.0061	0.0063	0.0064	0.0064	0.0065	0.0067	0.0068	0.0069	0.0070	0.0072	0.0073	0.0076	0.0078	0.0080	12
0.0060	0.0061	0.0062	0.0063	0.0064	0.0065	0.0066	0.0068	0.0069	0.0070	0.0072	0.0075	0.0077	0.0079	
0.0067	0.0068	0.0069	0.0070	0.0071	0.0072	0.0073	0.0074	0.0075	0.0077	0.0079	0.0081	0.0084	0.0086	10
0.0067	0.0068	0.0069	0.0070	0.0071	0.0072	0.0073	0.0074	0.0075	0.0077	0.0079	0.0081	0.0084	0.0086	
0.0074	0.0075	0.0076	0.0077	0.0078	0.0080	0.0081	0.0082	0.0083	0.0085	0.0086	0.0089	0.0091	0.0093	8
—	0.0072	0.0073	0.0074	0.0075	0.0076	0.0078	0.0079	0.0080	0.0082	0.0083	0.0086	0.0088	0.0090	
—	0.0080	0.0081	0.0082	0.0083	0.0085	0.0086	0.0087	0.0088	0.0090	0.0091	0.0094	0.0096	0.0098	7
—	—	0.0079	0.0080	0.0081	0.0082	0.0083	0.0084	0.0085	0.0087	0.0089	0.0091	0.0094	0.0096	
—	—	0.0088	0.0089	0.0089	0.0091	0.0092	0.0093	0.0094	0.0096	0.0098	0.0100	0.0103	0.0104	6
—	—	—	—	0.0098	0.0100	0.0101	0.0102	0.0103	0.0105	0.0107	0.0109	0.0111	0.0113	
—	—	—	—	0.0109	0.0111	0.0112	0.0113	0.0114	0.0116	0.0117	0.0120	0.0122	0.0124	4

NOTES

1. These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8N thread series.
2. Formula:
   Class 3B tolerances for internal threads are 0.75 times Class 2B tolerances and are determined by multiplying Class 2A tolerances (computed to six decimal places) by 0.975. See Note 2, Table 24, for formula for Class 2A tolerances.
3. Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement from 16 to 30 pitches are based on lengths of 20 pitches. For lengths of engagement not tabulated, the formula in Note 2 should be applied.
4. Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Note 2 should be applied.
5. Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement which are considered to be generally used. For other combinations encountered, see Limitations of Design, Appendix D.

TABLE 29—*Class 2, Pitch-Diameter Tolerances for Threads*

THREADS PER INCH	LENGTHS OF ENGAGEMENT		PITCH-DIAMETER TOLERANCES[a]								
	Number of pitches	Inches	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	3/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750
80	5 to 15	0.06 to 0.19	0.0018	0.0019	0.0020	0.0021	0.0023	—	—	—	—
	16 to 30	0.191 to 0.38	0.0020	0.0021	0.0022	0.0023	0.0024	—	—	—	—
72	5 to 15	0.07 to 0.21	0.0018	0.0020	0.0021	0.0022	0.0023	0.0026	—	—	—
	16 to 30	0.211 to 0.42	0.0020	0.0022	0.0023	0.0024	0.0025	0.0028	—	—	—
64	5 to 15	0.08 to 0.23	0.0019	0.0021	0.0021	0.0023	0.0024	0.0027	0.0029	—	—
	16 to 30	0.231 to 0.46	0.0022	0.0023	0.0024	0.0025	0.0027	0.0029	0.0031	—	—
56	5 to 15	0.09 to 0.27	0.0020	0.0022	0.0023	0.0024	0.0026	0.0028	0.0030	0.0031	0.0033
	16 to 30	0.271 to 0.54	0.0023	0.0024	0.0025	0.0027	0.0028	0.0030	0.0032	0.0034	0.0035
48	5 to 15	0.10 to 0.31	—	0.0023	0.0024	0.0026	0.0027	0.0029	0.0031	0.0033	0.0034
	16 to 30	0.311 to 0.62	—	0.0026	0.0027	0.0029	0.0030	0.0033	0.0034	0.0036	0.0037
40	5 to 15	0.12 to 0.38	—	—	0.0026	0.0027	0.0029	0.0031	0.0033	0.0035	0.0036
	16 to 30	0.381 to 0.76	—	—	0.0030	0.0031	0.0032	0.0035	0.0037	0.0038	0.0040
36	5 to 15	0.14 to 0.42	—	—	0.0027	0.0029	0.0030	0.0032	0.0034	0.0036	0.0037
	16 to 30	0.421 to 0.84	—	—	0.0031	0.0033	0.0034	0.0036	0.0038	0.0040	0.0041
32	5 to 15	0.16 to 0.47	—	—	0.0028	0.0030	0.0031	0.0034	0.0036	0.0037	0.0039
	16 to 30	0.471 to 0.94	—	—	0.0033	0.0035	0.0036	0.0038	0.0040	0.0042	0.0043
28	5 to 15	0.18 to 0.54	—	—	—	0.0032	0.0033	0.0035	0.0037	0.0039	0.0040
	16 to 30	0.541 to 1.08	—	—	—	0.0037	0.0038	0.0041	0.0043	0.0044	0.0046
24	5 to 15	0.21 to 0.62	—	—	—	0.0034	0.0035	0.0038	0.0040	0.0041	0.0043
	16 to 30	0.621 to 1.24	—	—	—	0.0040	0.0041	0.0044	0.0046	0.0047	0.0049
20	5 to 15	0.25 to 0.75	—	—	—	—	0.0038	0.0041	0.0042	0.0044	0.0046
	16 to 30	0.751 to 1.50	—	—	—	—	0.0046	0.0048	0.0050	0.0051	0.0053
18	5 to 15	0.28 to 0.83	—	—	—	—	—	0.0042	0.0044	0.0046	0.0048
	16 to 30	0.831 to 1.66	—	—	—	—	—	0.0051	0.0052	0.0054	0.0056
16	5 to 15	0.31 to 0.94	—	—	—	—	—	0.0045	0.0047	0.0048	0.0050
	16 to 30	0.941 to 1.88	—	—	—	—	—	0.0054	0.0056	0.0057	0.0059
14	5 to 15	0.36 to 1.07	—	—	—	—	—	—	0.0049	0.0051	0.0053
	16 to 30	1.071 to 2.14	—	—	—	—	—	—	0.0060	0.0062	0.0063
12	5 to 15	0.42 to 1.25	—	—	—	—	—	—	0.0053	0.0055	0.0056
	16 to 30	1.251 to 2.50	—	—	—	—	—	—	0.0065	0.0067	0.0068
10	5 to 15	0.50 to 1.50	—	—	—	—	—	—	—	—	0.0061
	16 to 30	1.501 to 3.00	—	—	—	—	—	—	—	—	0.0076
8	5 to 15	0.62 to 1.88	—	—	—	—	—	—	—	—	—
	16 to 30	1.881 to 3.76	—	—	—	—	—	—	—	—	—
7	5 to 15	0.71 to 2.14	—	—	—	—	—	—	—	—	—
	16 to 30	2.141 to 4.29	—	—	—	—	—	—	—	—	—
6	5 to 15	0.83 to 2.50	—	—	—	—	—	—	—	—	—
	16 to 30	2.501 to 5.00	—	—	—	—	—	—	—	—	—
4	5 to 15	1.25 to 3.75	—	—	—	—	—	—	—	—	—
	16 to 30	3.751 to 7.50	—	—	—	—	—	—	—	—	—

[a] Tolerances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

of Special Diameters, Pitches, and Lengths of Engagement

PITCH-DIAMETER TOLERANCES[a]													THREADS PER INCH
1 0.8751 to 1.1250	1¼ 1.1251 to 1.3750	1½ 1.3751 to 1.6250	1¾ 1.6251 to 1.8750	2 1.8751 to 2.2500	2½ 2.2501 to 2.7500	3 2.7501 to 3.2500	3½ 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	
—	—	NOTES												80
—	—	1. These values do not agree with and shall not be used in place of any tabulated values for the NC, NF, 8N, 12N, 16N, and NEF thread series, and selected diameter-pitch combinations in Tables 15 and 19.												
—	—	2. Formula: Class 2 tolerances $= 0.002\sqrt{D} + 0.00133\,L_e + 0.010\sqrt{p}$ where D = basic major diameter, L_e = length of engagement, p = pitch												72
—	—													64
—	—	3. Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement from 16 to 30 pitches are based on lengths of 20 pitches. For lengths of engagement not tabulated, the formula in Note 2 should be applied.												56
—	—	4. Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Note 2 should be applied.												48
0.0039	—	5. Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement which are considered to be generally used. For other combinations encountered, see Limitations of Design, Appendix D.												
0.0042	—													40
0.0040	0.0042	0.0044	—	—	—	—	—	—	—	—	—	—	—	36
0.0044	0.0046	0.0049	—	—	—	—	—	—	—	—	—	—	—	
0.0041	0.0044	0.0046	0.0048	0.0050	0.0053	0.0056	—	—	—	—	—	—	—	32
0.0046	0.0048	0.0050	0.0052	0.0054	0.0058	0.0061	—	—	—	—	—	—	—	
0.0043	0.0046	0.0048	0.0050	0.0051	0.0055	0.0058	0.0061	0.0063	—	—	—	—	—	28
0.0048	0.0051	0.0053	0.0055	0.0057	0.0060	0.0063	0.0066	0.0068	—	—	—	—	—	
0.0045	0.0048	0.0050	0.0052	0.0054	0.0057	0.0060	0.0063	0.0065	0.0070	0.0074	—	—	—	24
0.0051	0.0054	0.0056	0.0058	0.0060	0.0063	0.0066	0.0069	0.0071	0.0076	0.0080	—	—	—	
0.0048	0.0051	0.0053	0.0055	0.0057	0.0060	0.0063	0.0066	0.0068	0.0073	0.0077	—	—	—	20
0.0056	0.0058	0.0060	0.0062	0.0064	0.0067	0.0070	0.0073	0.0076	0.0080	0.0085	—	—	—	
0.0050	0.0053	0.0055	0.0057	0.0058	0.0062	0.0065	0.0068	0.0070	0.0075	0.0079	0.0087	—	—	18
0.0058	0.0061	0.0063	0.0065	0.0067	0.0070	0.0073	0.0076	0.0078	0.0083	0.0087	0.0095	—	—	
0.0052	0.0055	0.0057	0.0059	0.0061	0.0064	0.0067	0.0070	0.0072	0.0077	0.0081	0.0089	0.0096	—	16
0.0062	0.0064	0.0066	0.0068	0.0070	0.0073	0.0076	0.0079	0.0082	0.0086	0.0091	0.0098	0.0105	—	
0.0055	0.0058	0.0060	0.0062	0.0064	0.0067	0.0070	0.0073	0.0075	0.0080	0.0084	0.0092	0.0099	0.0105	14
0.0066	0.0068	0.0070	0.0072	0.0074	0.0077	0.0080	0.0083	0.0086	0.0090	0.0095	0.0102	0.0109	0.0115	
0.0059	0.0061	0.0063	0.0065	0.0067	0.0070	0.0073	0.0076	0.0079	0.0084	0.0088	0.0095	0.0102	0.0108	12
0.0071	0.0073	0.0076	0.0078	0.0079	0.0083	0.0086	0.0088	0.0091	0.0096	0.0100	0.0108	0.0114	0.0120	
0.0064	0.0066	0.0068	0.0070	0.0072	0.0075	0.0078	0.0081	0.0084	0.0088	0.0093	0.0100	0.0107	0.0113	10
0.0078	0.0081	0.0083	0.0085	0.0086	0.0090	0.0093	0.0096	0.0098	0.0103	0.0107	0.0115	0.0121	0.0128	
0.0070	0.0073	0.0075	0.0077	0.0079	0.0082	0.0085	0.0088	0.0090	0.0095	0.0099	0.0107	0.0114	0.0120	8
0.0089	0.0091	0.0093	0.0095	0.0097	0.0100	0.0103	0.0106	0.0109	0.0113	0.0118	0.0125	0.0132	0.0138	
—	0.0077	0.0079	0.0081	0.0083	0.0087	0.0090	0.0092	0.0095	0.0100	0.0104	0.0111	0.0118	0.0124	7
—	0.0098	0.0100	0.0102	0.0104	0.0107	0.0110	0.0113	0.0116	0.0121	0.0125	0.0132	0.0139	0.0145	
—	—	0.0085	0.0087	0.0089	0.0092	0.0095	0.0098	0.0101	0.0105	0.0110	0.0117	0.0124	0.0130	6
—	—	0.0110	0.0112	0.0113	0.0117	0.0120	0.0123	0.0125	0.0130	0.0134	0.0142	0.0148	0.0154	
—	—	—	—	0.0108	0.0112	0.0115	0.0117	0.0120	0.0125	0.0129	0.0136	0.0143	0.0149	4
—	—	—	—	0.0145	0.0148	0.0151	0.0154	0.0156	0.0161	0.0165	0.0173	0.0180	0.0186	

TABLE 30—*Class 3, Pitch-Diameter Tolerances for Threads*

THREADS PER INCH	LENGTHS OF ENGAGEMENT		PITCH-DIAMETER TOLERANCES[a]								
	Number of pitches	Inches	1/16 0.0600 to 0.0781	3/32 0.0782 to 0.1094	1/8 0.1095 to 0.1563	3/16 0.1564 to 0.2188	1/4 0.2189 to 0.3125	3/8 0.3126 to 0.4375	1/2 0.4376 to 0.5625	5/8 0.5626 to 0.6875	3/4 0.6876 to 0.8750
80	5 to 15	0.06 to 0.19	0.0012	0.0013	0.0014	0.0015	0.0016	—	—	—	—
	16 to 30	0.191 to 0.38	0.0014	0.0014	0.0015	0.0016	0.0017	—	—	—	—
72	5 to 15	0.07 to 0.21	0.0013	0.0014	0.0014	0.0015	0.0016	0.0018	—	—	—
	16 to 30	0.211 to 0.42	0.0014	0.0015	0.0016	0.0017	0.0018	0.0019	—	—	—
64	5 to 15	0.08 to 0.23	0.0014	0.0014	0.0015	0.0016	0.0017	0.0019	0.0020	—	—
	16 to 30	0.231 to 0.46	0.0015	0.0016	0.0017	0.0018	0.0019	0.0020	0.0022	—	—
56	5 to 15	0.09 to 0.27	0.0014	0.0015	0.0016	0.0017	0.0018	0.0019	0.0021	0.0022	0.0023
	16 to 30	0.271 to 0.54	0.0016	0.0017	0.0018	0.0019	0.0020	0.0021	0.0023	0.0024	0.0025
48	5 to 15	0.10 to 0.31	—	0.0016	0.0017	0.0018	0.0019	0.0020	0.0022	0.0023	0.0024
	16 to 30	0.311 to 0.62	—	0.0018	0.0019	0.0020	0.0021	0.0023	0.0024	0.0025	0.0026
40	5 to 15	0.12 to 0.38	—	—	0.0018	0.0019	0.0020	0.0022	0.0023	0.0024	0.0025
	16 to 30	0.381 to 0.76	—	—	0.0021	0.0022	0.0023	0.0024	0.0026	0.0027	0.0028
36	5 to 15	0.14 to 0.42	—	—	0.0019	0.0020	0.0021	0.0023	0.0024	0.0025	0.0026
	16 to 30	0.421 to 0.84	—	—	0.0022	0.0023	0.0024	0.0025	0.0027	0.0028	0.0029
32	5 to 15	0.16 to 0.47	—	—	0.0020	0.0021	0.0022	0.0024	0.0025	0.0026	0.0027
	16 to 30	0.471 to 0.94	—	—	0.0023	0.0024	0.0025	0.0027	0.0028	0.0029	0.0030
28	5 to 15	0.18 to 0.54	—	—	—	0.0022	0.0023	0.0025	0.0026	0.0027	0.0028
	16 to 30	0.541 to 1.08	—	—	—	0.0026	0.0027	0.0028	0.0030	0.0031	0.0032
24	5 to 15	0.21 to 0.62	—	—	—	0.0024	0.0025	0.0026	0.0028	0.0029	0.0030
	16 to 30	0.621 to 1.24	—	—	—	0.0028	0.0029	0.0031	0.0032	0.0033	0.0034
20	5 to 15	0.25 to 0.75	—	—	—	—	0.0027	0.0028	0.0030	0.0031	0.0032
	16 to 30	0.751 to 1.50	—	—	—	—	0.0032	0.0034	0.0035	0.0036	0.0037
18	5 to 15	0.28 to 0.83	—	—	—	—	—	0.0030	0.0031	0.0032	0.0033
	16 to 30	0.831 to 1.66	—	—	—	—	—	0.0035	0.0037	0.0038	0.0039
16	5 to 15	0.31 to 0.94	—	—	—	—	—	0.0031	0.0033	0.0034	0.0035
	16 to 30	0.941 to 1.88	—	—	—	—	—	0.0038	0.0039	0.0040	0.0041
14	5 to 15	0.36 to 1.07	—	—	—	—	—	—	0.0035	0.0036	0.0037
	16 to 30	1.071 to 2.14	—	—	—	—	—	—	0.0042	0.0043	0.0044
12	5 to 15	0.42 to 1.25	—	—	—	—	—	—	0.0037	0.0038	0.0039
	16 to 30	1.251 to 2.50	—	—	—	—	—	—	0.0046	0.0047	0.0048
10	5 to 15	0.50 to 1.50	—	—	—	—	—	—	—	—	0.0043
	16 to 30	1.501 to 3.00	—	—	—	—	—	—	—	—	0.0053
8	5 to 15	0.62 to 1.88	—	—	—	—	—	—	—	—	—
	16 to 30	1.881 to 3.76	—	—	—	—	—	—	—	—	—
7	5 to 15	0.71 to 2.14	—	—	—	—	—	—	—	—	—
	16 to 30	2.141 to 4.29	—	—	—	—	—	—	—	—	—
6	5 to 15	0.83 to 2.50	—	—	—	—	—	—	—	—	—
	16 to 30	2.501 to 5.00	—	—	—	—	—	—	—	—	—
4	5 to 15	1.25 to 3.75	—	—	—	—	—	—	—	—	—
	16 to 30	3.751 to 7.50	—	—	—	—	—	—	—	—	—

[a] Tolerances are based on diameters given in common fractions, which are the means of the diameter ranges expressed in decimals.

of Special Diameters, Pitches, and Lengths of Engagement

PITCH-DIAMETER TOLERANCES[a]														THREADS PER INCH
1 0.8751 to 1.1250	1 ¼ 1.1251 to 1.3750	1 ½ 1.3751 to 1.6250	1 ¾ 1.6251 to 1.8750	2 1.8751 to 2.2500	2 ½ 2.2501 to 2.7500	3 2.7501 to 3.2500	3 ½ 3.2501 to 3.7500	4 3.7501 to 4.5000	5 4.5001 to 5.5000	6 5.5001 to 7.0000	8 7.0001 to 9.0000	10 9.0001 to 11.0000	12 11.0001 to 13.0000	
—	—	NOTES												80
—	—	1. These values do not agree with and shall not be used in place of any tabulated values for the NC, NF, 8N, 12N, 16N, and NEF thread series, and selected diameter-pitch combinations in Tables 16 and 20.												
—	—	2. Formula: Class 3 tolerances are determined by multiplying Class 2 tolerances (computed to six decimal places) by 0.7. See Note 2, Table 29, for formula for Class 2 tolerances.												72
—	—	3. Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement from 16 to 30 pitches are based on lengths of 20 pitches. For lengths of engagement not tabulated, the formula in Note 2 should be applied.												64
—	—	4. Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Note 2 should be applied.												56
—	—	5. Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement which are considered to be generally used. For other combinations encountered, see Limitations of Design, Appendix D.												48
0.0027	—													40
0.0030	—													
0.0028	0.0030	0.0031	—	—	—	—	—	—	—	—	—	—	—	36
0.0031	0.0032	0.0034	—	—	—	—	—	—	—	—	—	—	—	
0.0029	0.0031	0.0032	0.0034	0.0035	0.0037	0.0039	—	—	—	—	—	—	—	32
0.0032	0.0034	0.0035	0.0037	0.0038	0.0040	0.0042	—	—	—	—	—	—	—	
0.0030	0.0032	0.0033	0.0035	0.0036	0.0038	0.0040	0.0042	0.0044	—	—	—	—	—	28
0.0034	0.0036	0.0037	0.0038	0.0040	0.0042	0.0044	0.0046	0.0048	—	—	—	—	—	
0.0032	0.0033	0.0035	0.0036	0.0038	0.0040	0.0042	0.0044	0.0046	0.0049	0.0052	—	—	—	24
0.0036	0.0038	0.0039	0.0041	0.0042	0.0044	0.0046	0.0048	0.0050	0.0053	0.0056	—	—	—	
0.0034	0.0035	0.0037	0.0038	0.0040	0.0042	0.0044	0.0046	0.0048	0.0051	0.0054	—	—	—	20
0.0039	0.0041	0.0042	0.0043	0.0045	0.0047	0.0049	0.0051	0.0053	0.0056	0.0059	—	—	—	
0.0035	0.0037	0.0038	0.0040	0.0041	0.0043	0.0045	0.0047	0.0049	0.0052	0.0055	0.0061	—	—	18
0.0041	0.0042	0.0044	0.0045	0.0047	0.0049	0.0051	0.0053	0.0055	0.0058	0.0061	0.0066	—	—	
0.0037	0.0038	0.0040	0.0041	0.0043	0.0045	0.0047	0.0049	0.0051	0.0054	0.0057	0.0062	0.0067	—	16
0.0043	0.0045	0.0046	0.0048	0.0049	0.0051	0.0053	0.0055	0.0057	0.0060	0.0063	0.0069	0.0073	—	
0.0039	0.0040	0.0042	0.0043	0.0044	0.0047	0.0049	0.0051	0.0053	0.0056	0.0059	0.0064	0.0069	0.0073	14
0.0046	0.0048	0.0049	0.0051	0.0052	0.0054	0.0056	0.0058	0.0060	0.0063	0.0066	0.0072	0.0076	0.0081	
0.0041	0.0043	0.0044	0.0046	0.0047	0.0049	0.0051	0.0053	0.0055	0.0058	0.0061	0.0067	0.0071	0.0076	12
0.0050	0.0051	0.0053	0.0054	0.0056	0.0058	0.0060	0.0062	0.0064	0.0067	0.0070	0.0075	0.0080	0.0084	
0.0045	0.0046	0.0048	0.0049	0.0050	0.0053	0.0055	0.0057	0.0059	0.0062	0.0065	0.0070	0.0075	0.0079	10
0.0055	0.0056	0.0058	0.0059	0.0061	0.0063	0.0065	0.0067	0.0069	0.0072	0.0075	0.0080	0.0085	0.0089	
0.0049	0.0051	0.0052	0.0054	0.0055	0.0057	0.0059	0.0061	0.0063	0.0067	0.0070	0.0075	0.0079	0.0084	8
0.0062	0.0064	0.0065	0.0067	0.0068	0.0070	0.0072	0.0074	0.0076	0.0079	0.0082	0.0088	0.0092	0.0097	
—	0.0054	0.0056	0.0057	0.0058	0.0061	0.0063	0.0065	0.0066	0.0070	0.0073	0.0078	0.0083	0.0087	7
—	0.0069	0.0070	0.0072	0.0073	0.0075	0.0077	0.0079	0.0081	0.0084	0.0087	0.0093	0.0097	0.0102	
—	—	0.0060	0.0061	0.0062	0.0065	0.0067	0.0069	0.0071	0.0074	0.0077	0.0082	0.0087	0.0091	6
—	—	0.0077	0.0078	0.0079	0.0082	0.0084	0.0086	0.0088	0.0091	0.0094	0.0099	0.0104	0.0108	
—	—	—	—	0.0076	0.0078	0.0080	0.0082	0.0084	0.0087	0.0090	0.0096	0.0100	0.0104	4
—	—	—	—	0.0101	0.0104	0.0106	0.0108	0.0110	0.0113	0.0116	0.0121	0.0126	0.0130	

TABLE 31a—*Classes 1B, 2B, and 3B, Minor-*

THREADS PER INCH	TOLERANCE RATIOS	LENGTHS OF ENGAGEMENT IN TERMS OF DIAMETER[b]		MINOR-DIAMETER TOLERANCES[c]								
		Above	To and including	0.060	0.073	0.086	0.099	0.112	0.125	0.138	0.164	0.190
				0.053 to 0.066	0.067 to 0.079	0.080 to 0.092	0.093 to 0.105	0.106 to 0.118	0.119 to 0.131	0.132 to 0.151	0.152 to 0.177	0.178 to 0.203
80	½	—	⅓ *D*	0.0035	0.0029	0.0025	0.0022	0.0020	0.0018	0.0017	0.0015	0.0013
	¾	⅓ *D*	⅔ *D*	0.0049	0.0044	0.0038	0.0034	0.0030	0.0028	0.0026	0.0022	0.0020
	1	⅔ *D*	1½ *D*	0.0049	0.0049	0.0049	0.0045	0.0040	0.0037	0.0034	0.0030	0.0027
	1¼	1½ *D*	3 *D*	0.0049	0.0049	0.0049	0.0049	0.0049	0.0046	0.0043	0.0037	0.0033
72	½	—	⅓ *D*	0.0039	0.0033	0.0029	0.0026	0.0023	0.0021	0.0020	0.0017	0.0015
	¾	⅓ *D*	⅔ *D*	0.0055	0.0049	0.0043	0.0038	0.0035	0.0032	0.0029	0.0026	0.0023
	1	⅔ *D*	1½ *D*	0.0055	0.0055	0.0055	0.0051	0.0046	0.0042	0.0039	0.0034	0.0031
	1¼	1½ *D*	3 *D*	0.0055	0.0055	0.0055	0.0055	0.0055	0.0053	0.0049	0.0043	0.0039
64	½	—	⅓ *D*	0.0045	0.0038	0.0033	0.0029	0.0027	0.0024	0.0023	0.0020	0.0018
	¾	⅓ *D*	⅔ *D*	0.0062	0.0057	0.0049	0.0044	0.0040	0.0037	0.0034	0.0030	0.0027
	1	⅔ *D*	1½ *D*	0.0062	0.0062	0.0062	0.0059	0.0053	0.0049	0.0045	0.0040	0.0036
	1¼	1½ *D*	3 *D*	0.0062	0.0062	0.0062	0.0062	0.0062	0.0061	0.0057	0.0050	0.0045
56	½	—	⅓ *D*	—	0.0044	0.0038	0.0034	0.0031	0.0029	0.0026	0.0023	0.0021
	¾	⅓ *D*	⅔ *D*	—	0.0066	0.0057	0.0051	0.0046	0.0043	0.0040	0.0035	0.0032
	1	⅔ *D*	1½ *D*	—	0.0070	0.0070	0.0068	0.0062	0.0057	0.0053	0.0047	0.0042
	1¼	1½ *D*	3 *D*	—	0.0070	0.0070	0.0070	0.0070	0.0070	0.0066	0.0059	0.0053
48	½	—	⅓ *D*	—	—	0.0045	0.0040	0.0037	0.0034	0.0032	0.0028	0.0025
	¾	⅓ *D*	⅔ *D*	—	—	0.0068	0.0061	0.0055	0.0051	0.0047	0.0042	0.0038
	1	⅔ *D*	1½ *D*	—	—	0.0082	0.0081	0.0074	0.0068	0.0063	0.0056	0.0051
	1¼	1½ *D*	3 *D*	—	—	0.0082	0.0082	0.0082	0.0082	0.0079	0.0070	0.0063
40	½	—	⅓ *D*	—	—	—	0.0049	0.0045	0.0041	0.0039	0.0034	0.0031
	¾	⅓ *D*	⅔ *D*	—	—	—	0.0074	0.0067	0.0062	0.0058	0.0051	0.0047
	1	⅔ *D*	1½ *D*	—	—	—	0.0098	0.0090	0.0083	0.0077	0.0068	0.0062
	1¼	1½ *D*	3 *D*	—	—	—	0.0098	0.0098	0.0098	0.0096	0.0086	0.0078
36	½	—	⅓ *D*	—	—	—	—	0.0050	0.0046	0.0043	0.0038	0.0035
	¾	⅓ *D*	⅔ *D*	—	—	—	—	0.0075	0.0069	0.0065	0.0058	0.0052
	1	⅔ *D*	1½ *D*	—	—	—	—	0.0100	0.0093	0.0086	0.0077	0.0070
	1¼	1½ *D*	3 *D*	—	—	—	—	0.0109	0.0109	0.0108	0.0096	0.0087
32	½	—	⅓ *D*	—	—	—	—	—	—	0.0049	0.0043	0.0039
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	0.0073	0.0065	0.0059
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	0.0098	0.0087	0.0079
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	0.0122	0.0108	0.0099
28	½	—	⅓ *D*	—	—	—	—	—	—	—	—	0.0045
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	0.0068
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	0.0091
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	0.0113
24	½	—	⅓ *D*	—	—	—	—	—	—	—	—	0.0053
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	0.0079
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	0.0106
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	0.0132

[a] If the minor-diameter tolerance as selected from this table is less than the pitch-diameter tolerance, use the latter. See Limitations of Design, Appendix D.
[b] Tolerances for lengths of engagement in terms of pitch should be selected from equivalent lengths of engagement in terms of diameter ranges.
[c] Tolerances are based on diameters given on upper line, which are the means of the nominal diameter ranges beneath them.

Diameter Tolerances[a] for Internal Special Threads

MINOR-DIAMETER TOLERANCES[c]													
0.216	0.250	0.3125	0.375	0.4375	0.500	0.5625	0.625	0.6875	0.750	0.8125	0.875	0.9375	1.000	THREADS PER INCH
0.204 to 0.233	0.234 to 0.281	0.282 to 0.344	0.345 to 0.406	0.407 to 0.469	0.470 to 0.531	0.532 to 0.594	0.595 to 0.656	0.657 to 0.719	0.720 to 0.781	0.782 to 0.844	0.845 to 0.906	0.907 to 0.969		
0.0013	0.0013	0.0013	—	—	—	—	—	—	—	—	—	—	—	
0.0020	0.0020	0.0020	—	—	—	—	—	—	—	—	—	—	—	
0.0026	0.0026	0.0026	—	—	—	—	—	—	—	—	—	—	—	80
0.0033	0.0033	0.0033	—	—	—	—	—	—	—	—	—	—	—	
0.0015	0.0015	0.0015	0.0015	0.0015	—	—	—	—	—	—	—	—	—	
0.0022	0.0022	0.0022	0.0022	0.0022	—	—	—	—	—	—	—	—	—	
0.0029	0.0029	0.0029	0.0029	0.0029	—	—	—	—	—	—	—	—	—	72
0.0036	0.0036	0.0036	0.0036	0.0036	—	—	—	—	—	—	—	—	—	
0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	—	—	—	—	—	—	—	
0.0025	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	—	—	—	—	—	—	—	
0.0033	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	—	—	—	—	—	—	—	64
0.0041	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	—	—	—	—	—	—	—	
0.0019	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	—	—	
0.0029	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	—	—	
0.0039	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	—	—	56
0.0049	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	—	—	
0.0023	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	—	—	
0.0035	0.0032	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	—	—	
0.0047	0.0043	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	—	—	48
0.0059	0.0054	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	—	—	
0.0029	0.0026	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	
0.0043	0.0040	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	
0.0057	0.0053	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	40
0.0072	0.0066	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	
0.0032	0.0030	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	
0.0048	0.0044	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	
0.0064	0.0059	0.0053	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	36
0.0081	0.0074	0.0066	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	
0.0036	0.0034	0.0030	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	
0.0055	0.0050	0.0045	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	
0.0073	0.0067	0.0060	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	32
0.0091	0.0084	0.0075	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	
0.0042	0.0039	0.0034	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	
0.0063	0.0058	0.0051	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047	
0.0084	0.0077	0.0069	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	28
0.0105	0.0096	0.0086	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	
0.0049	0.0045	0.0040	0.0037	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	
0.0073	0.0068	0.0060	0.0055	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	
0.0098	0.0090	0.0080	0.0073	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	24
0.0122	0.0113	0.0100	0.0092	0.0087	0.0087	0.0087	0.0087	0.0087	0.0087	0.0087	0.0087	0.0087	0.0087	

TABLE 31b—*Classes 1B, 2B, and 3B, Minor-*

THREADS PER INCH	TOLERANCE RATIOS	LENGTHS OF ENGAGEMENT IN TERMS OF DIAMETER[b]		MINOR-DIAMETER TOLERANCES[c]								
		Above	To and including	0.060	0.073	0.086	0.099	0.112	0.125	0.138	0.164	0.190
				0.053 to 0.066	0.067 to 0.079	0.080 to 0.092	0.093 to 0.105	0.106 to 0.118	0.119 to 0.131	0.132 to 0.151	0.152 to 0.177	0.178 to 0.203
20	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
18	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
16	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
14	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
12	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
10	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
8	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
7	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
6	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—
4	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—

[a] If the minor-diameter tolerance as selected from this table is less than the pitch-diameter tolerance, use the latter. See Limitations of Design, Appendix D.
[b] Tolerances for lengths of engagement in terms of pitch should be selected from equivalent lengths of engagement in terms of diameter ranges.
[c] Tolerances are based on diameters given on upper line, which are the means of the nominal diameter ranges beneath them.

Diameter Tolerances[a] for Internal Special Threads

MINOR-DIAMETER TOLERANCES[c]													
0.216	0.250	0.3125	0.375	0.4375	0.500	0.5625	0.625	0.6875	0.750	0.8125	0.875	0.9375	1.000	THREADS PER INCH
0.204 to 0.233	0.234 to 0.281	0.282 to 0.344	0.345 to 0.406	0.407 to 0.469	0.470 to 0.531	0.532 to 0.594	0.595 to 0.656	0.657 to 0.719	0.720 to 0.781	0.782 to 0.844	0.845 to 0.906	0.907 to 0.969		
—	0.0054	0.0048	0.0044	0.0041	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	
—	0.0081	0.0072	0.0066	0.0062	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	
—	0.0108	0.0096	0.0088	0.0082	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078	0.0078	20
—	0.0135	0.0120	0.0110	0.0103	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	
—	—	0.0053	0.0049	0.0045	0.0043	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	
—	—	0.0080	0.0073	0.0068	0.0065	0.0062	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	
—	—	0.0106	0.0097	0.0091	0.0086	0.0082	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	18
—	—	0.0133	0.0122	0.0114	0.0108	0.0103	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	
—	—	—	0.0054	0.0051	0.0048	0.0046	0.0044	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	
—	—	—	0.0082	0.0076	0.0072	0.0069	0.0067	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	
—	—	—	0.0109	0.0102	0.0096	0.0092	0.0089	0.0086	0.0085	0.0085	0.0085	0.0085	0.0085	16
—	—	—	0.0136	0.0127	0.0120	0.0115	0.0111	0.0108	0.0106	0.0106	0.0106	0.0106	0.0106	
—	—	—	—	0.0058	0.0054	0.0052	0.0050	0.0049	0.0047	0.0046	0.0045	0.0044	0.0044	
—	—	—	—	0.0086	0.0082	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0067	0.0066	
—	—	—	—	0.0115	0.0109	0.0104	0.0100	0.0097	0.0095	0.0092	0.0091	0.0089	0.0088	14
—	—	—	—	0.0144	0.0136	0.0130	0.0125	0.0122	0.0118	0.0116	0.0113	0.0111	0.0110	
—	—	—	—	—	0.0063	0.0060	0.0058	0.0056	0.0054	0.0053	0.0052	0.0051	0.0050	
—	—	—	—	—	0.0094	0.0090	0.0087	0.0084	0.0082	0.0080	0.0078	0.0077	0.0075	
—	—	—	—	—	0.0125	0.0120	0.0115	0.0112	0.0109	0.0106	0.0104	0.0102	0.0100	12
—	—	—	—	—	0.0157	0.0150	0.0144	0.0140	0.0136	0.0133	0.0130	0.0128	0.0125	
—	—	—	—	—	—	—	—	0.0066	0.0064	0.0062	0.0061	0.0060	0.0060	
—	—	—	—	—	—	—	—	0.0099	0.0096	0.0093	0.0092	0.0090	0.0090	
—	—	—	—	—	—	—	—	0.0131	0.0128	0.0125	0.0122	0.0120	0.0120	10
—	—	—	—	—	—	—	—	0.0164	0.0160	0.0156	0.0153	0.0150	0.0150	
—	—	—	—	—	—	—	—	—	—	0.0075	0.0075	0.0075	0.0075	
—	—	—	—	—	—	—	—	—	—	0.0112	0.0112	0.0112	0.0112	
—	—	—	—	—	—	—	—	—	—	0.0150	0.0150	0.0150	0.0150	8
—	—	—	—	—	—	—	—	—	—	0.0188	0.0188	0.0188	0.0188	
—	—	—	—	—	—	—	—	—	—	—	—	0.0086	0.0086	
—	—	—	—	—	—	—	—	—	—	—	—	0.0129	0.0129	
—	—	—	—	—	—	—	—	—	—	—	—	0.0171	0.0171	7
—	—	—	—	—	—	—	—	—	—	—	—	0.0214	0.0214	
—	—	—	—	—	—	—	—	—	—	—	—	—	0.0100	
—	—	—	—	—	—	—	—	—	—	—	—	—	0.0150	
—	—	—	—	—	—	—	—	—	—	—	—	—	0.0200	6
—	—	—	—	—	—	—	—	—	—	—	—	—	0.0250	
—	—	—	—	—	—	—	—	—	—	—	—	—	0.0150	
—	—	—	—	—	—	—	—	—	—	—	—	—	0.0225	
—	—	—	—	—	—	—	—	—	—	—	—	—	0.0300	4
—	—	—	—	—	—	—	—	—	—	—	—	—	0.0375	

TABLE 32a—*Classes 2 and 3, Minor-Diameter*

THREADS PER INCH	LENGTHS OF ENGAGEMENT IN TERMS OF DIAMETER[b]		MINOR-DIAMETER TOLERANCES FOR THREAD SIZES HAVING BASIC MAJOR DIAMETERS											
	Tolerances based on →		0.060	0.073	0.086	0.099	0.112	0.125	0.138	0.164	0.190	0.216	0.250	0.3125
	Tolerance ratios ↓	Above →	0.053	0.066	0.079	0.092	0.105	0.118	0.131	0.151	0.177	0.203	0.233	0.281
		to → and including	0.066	0.079	0.092	0.105	0.118	0.131	0.151	0.177	0.203	0.233	0.281	0.344
80	½	—	⅛ D	0.0027	0.0022	0.0017	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
	¾	⅛ D	⅜ D	0.0041	0.0033	0.0026	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
	1	⅜ D	1½ D	0.0049	0.0044	0.0034	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026
	1¼	1½ D	3 D	0.0049	0.0049	0.0042	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033
72	½	—	⅛ D	0.0032	0.0027	0.0022	0.0017	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
	¾	⅛ D	⅜ D	0.0048	0.0040	0.0033	0.0025	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
	1	⅜ D	1½ D	0.0054	0.0054	0.0044	0.0033	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027
	1¼	1½ D	3 D	0.0054	0.0054	0.0054	0.0041	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034
64	½	—	⅛ D	0.0038	0.0033	0.0028	0.0022	0.0017	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
	¾	⅛ D	⅜ D	0.0057	0.0049	0.0041	0.0034	0.0026	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
	1	⅜ D	1½ D	0.0062	0.0062	0.0055	0.0045	0.0035	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028
	1¼	1½ D	3 D	0.0062	0.0062	0.0062	0.0056	0.0044	0.0035	0.0035	0.0035	0.0035	0.0038	0.0042	
56	½	—	⅛ D	—	0.0040	0.0035	0.0029	0.0024	0.0019	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
	¾	⅛ D	⅜ D	—	0.0060	0.0052	0.0044	0.0037	0.0029	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
	1	⅜ D	1½ D	—	0.0070	0.0069	0.0059	0.0049	0.0038	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030
	1¼	1½ D	3 D	—	0.0070	0.0070	0.0070	0.0061	0.0048	0.0038	0.0038	0.0038	0.0038	0.0038	0.0044
48	½	—	⅛ D	—	—	0.0044	0.0039	0.0033	0.0028	0.0023	0.0016	0.0016	0.0016	0.0016	0.0016
	¾	⅛ D	⅜ D	—	—	0.0066	0.0058	0.0050	0.0042	0.0035	0.0024	0.0024	0.0024	0.0024	0.0024
	1	⅜ D	1½ D	—	—	0.0082	0.0077	0.0067	0.0057	0.0046	0.0032	0.0032	0.0032	0.0032	0.0032
	1¼	1½ D	3 D	—	—	0.0082	0.0082	0.0082	0.0071	0.0058	0.0041	0.0041	0.0041	0.0041	0.0046
40	½	—	⅛ D	—	—	—	0.0050	0.0045	0.0040	0.0035	0.0025	0.0020	0.0019	0.0019	0.0019
	¾	⅛ D	⅜ D	—	—	—	0.0076	0.0068	0.0060	0.0053	0.0037	0.0030	0.0029	0.0029	0.0029
	1	⅜ D	1½ D	—	—	—	0.0098	0.0091	0.0080	0.0070	0.0050	0.0040	0.0039	0.0039	0.0039
	1¼	1½ D	3 D	—	—	—	0.0098	0.0098	0.0098	0.0088	0.0063	0.0049	0.0049	0.0049	0.0049
36	½	—	⅛ D	—	—	—	—	0.0053	0.0048	0.0043	0.0032	0.0022	0.0022	0.0022	0.0022
	¾	⅛ D	⅜ D	—	—	—	—	0.0079	0.0072	0.0064	0.0049	0.0033	0.0032	0.0032	0.0032
	1	⅜ D	1½ D	—	—	—	—	0.0106	0.0095	0.0085	0.0065	0.0044	0.0043	0.0043	0.0043
	1¼	1½ D	3 D	—	—	—	—	0.0109	0.0109	0.0106	0.0081	0.0055	0.0052	0.0054	0.0054
32	½	—	⅛ D	—	—	—	—	—	—	0.0052	0.0041	0.0031	0.0026	0.0024	0.0024
	¾	⅛ D	⅜ D	—	—	—	—	—	—	0.0077	0.0062	0.0046	0.0040	0.0037	0.0037
	1	⅜ D	1½ D	—	—	—	—	—	—	0.0103	0.0082	0.0062	0.0053	0.0049	0.0049
	1¼	1½ D	3 D	—	—	—	—	—	—	0.0123	0.0103	0.0078	0.0066	0.0061	0.0061
28	½	—	⅛ D	—	—	—	—	—	—	—	—	0.0042	0.0033	0.0030	0.0028
	¾	⅛ D	⅜ D	—	—	—	—	—	—	—	—	0.0068	0.0050	0.0044	0.0042
	1	⅜ D	1½ D	—	—	—	—	—	—	—	—	0.0084	0.0066	0.0059	0.0056
	1¼	1½ D	3 D	—	—	—	—	—	—	—	—	0.0104	0.0083	0.0074	0.0070
24	½	—	⅛ D	—	—	—	—	—	—	—	—	0.0055	0.0045	0.0038	0.0032
	¾	⅛ D	⅜ D	—	—	—	—	—	—	—	—	0.0083	0.0067	0.0057	0.0049
	1	⅜ D	1½ D	—	—	—	—	—	—	—	—	0.0110	0.0090	0.0077	0.0065
	1¼	1½ D	3 D	—	—	—	—	—	—	—	—	0.0138	0.0112	0.0096	0.0081

[a] If the minor-diameter tolerance as selected from this table is less than the pitch-diameter tolerance, use the latter. See Limitations of Design, Appendix D.
[b] Tolerance for lengths of engagement in terms of pitch should be selected from equivalent lengths of engagement in terms of diameter ranges.
[c] Same as respective pitch-diameter tolerances for each class, but not less than values in preceding column.

Tolerances[a] for Internal Special Threads

MINOR-DIAMETER TOLERANCES FOR THREAD SIZES HAVING BASIC MAJOR DIAMETERS														
0.375	0.4375	0.500	0.5625	0.625	0.6875	0.750	0.8125	0.875	0.9375	1.000	1.250	2.000	3.500		THREADS PER INCH
0.344	0.406	0.469	0.531	0.594	0.656	0.719	0.781	0.844	0.906	0.969	1.031	1.500	2.5	4.5°	
0.406	0.469	0.531	0.594	0.656	0.719	0.781	0.844	0.906	0.969	1.031	1.500	2.5	4.5		
0.0013	0.0013	—	—	—	—	—	—	—	—	—	—	—	—	—	
0.0020	0.0020	—	—	—	—	—	—	—	—	—	—	—	—	—	
0.0026	0.0026	—	—	—	—	—	—	—	—	—	—	—	—	—	80
0.0033	0.0033	—	—	—	—	—	—	—	—	—	—	—	—	—	
0.0013	0.0013	0.0013	0.0014	0.0014	0.0015	0.0015	—	—	—	—	—	—	—	—	
0.0020	0.0020	0.0020	0.0021	0.0022	0.0022	0.0023	—	—	—	—	—	—	—	—	
0.0027	0.0027	0.0027	0.0028	0.0029	0.0030	0.0031	—	—	—	—	—	—	—	—	72
0.0034	0.0034	0.0034	0.0039	0.0042	0.0042	0.0042	—	—	—	—	—	—	—	—	
0.0014	0.0014	0.0014	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0018	—	—	—	
0.0021	0.0021	0.0021	0.0021	0.0022	0.0022	0.0023	0.0024	0.0025	0.0025	0.0025	0.0026	—	—	—	
0.0028	0.0028	0.0028	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034	0.0034	0.0035	—	—	—	64
0.0044	0.0044	0.0044	0.0044	0.0047	0.0047	0.0047	0.0050	0.0050	0.0050	0.0050	0.0052	—	—	—	
0.0015	0.0015	0.0015	0.0015	0.0016	0.0016	0.0016	0.0016	0.0017	0.0018	0.0018	0.0020	—	—	—	
0.0023	0.0023	0.0023	0.0023	0.0023	0.0024	0.0024	0.0025	0.0025	0.0026	0.0027	0.0031	—	—	—	
0.0030	0.0030	0.0030	0.0030	0.0031	0.0032	0.0032	0.0033	0.0034	0.0035	0.0036	0.0041	—	—	—	56
0.0046	0.0046	0.0046	0.0049	0.0049	0.0052	0.0052	0.0056	0.0056	0.0056	0.0056	0.0056	—	—	—	
0.0016	0.0016	0.0016	0.0016	0.0016	0.0018	0.0018	0.0020	0.0020	0.0020	0.0020	0.0022	0.0022	—	—	
0.0024	0.0024	0.0024	0.0024	0.0024	0.0028	0.0028	0.0029	0.0029	0.0029	0.0029	0.0033	0.0033	—	—	
0.0032	0.0032	0.0034	0.0037	0.0037	0.0037	0.0037	0.0039	0.0039	0.0039	0.0039	0.0044	0.0044	—	—	48
0.0048	0.0048	0.0048	0.0051	0.0051	0.0057	0.0057	0.0059	0.0062	0.0062	0.0062	0.0062	0.0062	—	—	
0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0020	0.0022	0.0024	—	—
0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0031	0.0034	0.0036	—	—
0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0041	0.0041	0.0041	0.0041	0.0045	0.0048	—	—	40
0.0049	0.0049	0.0051	0.0054	0.0054	0.0057	0.0057	0.0062	0.0068	0.0068	0.0068	0.0068	0.0068	—	—	
0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0023	0.0025	0.0025	—	
0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0035	0.0038	0.0038	—	
0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0046	0.0050	0.0050	—	36
0.0054	0.0054	0.0054	0.0057	0.0057	0.0057	0.0057	0.0065	0.0070	0.0070	0.0070	0.0072	0.0072	0.0072	—	
0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0027	0.0027	—	
0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0041	0.0041	—	
0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0054	0.0054	0.0054	—	32
0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0061	0.0065	0.0070	0.0070	0.0070	0.0076	0.0076	0.0076	—	
0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0031	—	
0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0046	—	
0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0062	0.0062	—	28
0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0079	0.0086	0.0086	—	
0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0033	—	
0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049	—	
0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0066	—	24
0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0089	0.0092	—	

TABLE 32b—*Classes 2 and 3, Minor-Diameter*

THREADS PER INCH	LENGTHS OF ENGAGEMENT IN TERMS OF DIAMETER[b]			MINOR-DIAMETER TOLERANCES FOR THREAD SIZES HAVING BASIC MAJOR DIAMETERS											
	Tolerances based on →			0.060	0.073	0.086	0.099	0.112	0.125	0.138	0.164	0.190	0.216	0.250	0.3125
	Tolerance ratios ↓	↓Above →		0.053	0.066	0.079	0.092	0.105	0.118	0.131	0.151	0.177	0.203	0.233	0.281
			to → and including ↓	0.066	0.079	0.092	0.105	0.118	0.131	0.151	0.177	0.203	0.233	0.281	0.344
20	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	0.0050	0.0044
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	0.0076	0.0066
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	0.0101	0.0088
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	0.0126	0.0110
18	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	0.0052
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	0.0078
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	0.0104
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	0.0130
16	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	—
14	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	—
12	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	—
10	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	—
8	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	—
7	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	—
6	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	—
4	½	—	⅓ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	¾	⅓ *D*	⅔ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1	⅔ *D*	1½ *D*	—	—	—	—	—	—	—	—	—	—	—	—
	1¼	1½ *D*	3 *D*	—	—	—	—	—	—	—	—	—	—	—	—

[a] If the minor-diameter tolerance as selected from this table is less than the pitch-diameter tolerance, use the latter. See Limitations of Design, Appendix D.
[b] Tolerance for lengths of engagement in terms of pitch should be selected from equivalent lengths of engagement in terms of diameter ranges.
[c] Same as respective pitch-diameter tolerances for each class, but not less than values in preceding column.

Tolerances[a] for Internal Special Threads

MINOR-DIAMETER TOLERANCES FOR THREAD SIZES HAVING BASIC MAJOR DIAMETERS															THREADS PER INCH
0.375	0.4375	0.500	0.5625	0.625	0.6875	0.750	0.8125	0.875	0.9375	1.000	1.250	2.000	3.500		
0.344	0.406	0.469	0.531	0.594	0.656	0.719	0.781	0.844	0.906	0.969	1.031	1.500	2.5	4.5°	
0.406	0.469	0.531	0.594	0.656	0.719	0.781	0.844	0.906	0.969	0.031	1.500	2.5	4.5		
0.0037	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	—	
0.0056	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	—	20
0.0075	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	—	
0.0094	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0102	0.0102	0.0102	0.0102	—	
0.0045	0.0039	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	—	
0.0068	0.0058	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	—	
0.0091	0.0078	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0082	—	18
0.0113	0.0097	0.0095	0.0095	0.0095	0.0095	0.0095	0.0095	0.0095	0.0095	0.0114	0.0114	0.0114	0.0114	—	
0.0055	0.0049	0.0042	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	—	
0.0083	0.0073	0.0063	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	—	
0.0110	0.0097	0.0084	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0085	—	16
0.0138	0.0131	0.0114	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0115	0.0120	0.0123	0.0126	—	
—	0.0061	0.0055	0.0048	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	—	
—	0.0092	0.0083	0.0072	0.0062	0.0062	0.0062	0.0062	0.0062	0.0062	0.0062	0.0062	0.0062	0.0062	—	
—	0.0123	0.0110	0.0096	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0096	0.0098	0.0098	—	14
—	0.0154	0.0138	0.0120	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0115	0.0127	0.0133	0.0139	—	
—	—	—	0.0065	0.0058	0.0052	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	—	
—	—	—	0.0097	0.0087	0.0077	0.0067	0.0067	0.0067	0.0067	0.0067	0.0067	0.0067	0.0067	—	
—	—	—	0.0129	0.0116	0.0103	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0098	0.0108	—	12
—	—	—	0.0161	0.0145	0.0129	0.0112	0.0112	0.0112	0.0112	0.0127	0.0131	0.0137	0.0143	—	
—	—	—	—	—	0.0074	0.0068	0.0061	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	—	
—	—	—	—	—	0.0111	0.0101	0.0092	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	—	
—	—	—	—	—	0.0148	0.0135	0.0122	0.0108	0.0108	0.0108	0.0108	0.0108	0.0112	—	10
—	—	—	—	—	0.0185	0.0169	0.0152	0.0135	0.0135	0.0135	0.0135	0.0184	0.0184	—	
—	—	—	—	—	—	—	0.0094	0.0087	0.0081	0.0074	0.0063	0.0063	0.0063	—	
—	—	—	—	—	—	—	0.0140	0.0130	0.0121	0.0111	0.0101	0.0101	0.0101	—	
—	—	—	—	—	—	—	0.0187	0.0174	0.0161	0.0148	0.0135	0.0135	0.0135	—	8
—	—	—	—	—	—	—	0.0234	0.0218	0.0201	0.0180	0.0169	0.0195	0.0210	—	
—	—	—	—	—	—	—	—	—	0.0087	0.0084	0.0077	0.0077	0.0077	—	
—	—	—	—	—	—	—	—	—	0.0131	0.0126	0.0116	0.0116	0.0116	—	
—	—	—	—	—	—	—	—	—	0.0175	0.0168	0.0154	0.0154	0.0154	—	7
—	—	—	—	—	—	—	—	—	0.0218	0.0211	0.0192	0.0192	0.0192	—	
—	—	—	—	—	—	—	—	—	—	0.0090	0.0090	0.0090	0.0090	—	
—	—	—	—	—	—	—	—	—	—	0.0135	0.0135	0.0135	0.0135	—	
—	—	—	—	—	—	—	—	—	—	0.0180	0.0180	0.0180	0.0180	—	6
—	—	—	—	—	—	—	—	—	—	0.0226	0.0226	0.0226	0.0226	—	
—	—	—	—	—	—	—	—	—	—	—	0.0135	0.0135	0.0135	—	
—	—	—	—	—	—	—	—	—	—	—	0.0203	0.0203	0.0203	—	
—	—	—	—	—	—	—	—	—	—	—	0.0270	0.0270	0.0270	—	4
—	—	—	—	—	—	—	—	—	—	—	0.0337	0.0337	0.0337	—	

Appendix A—Terminology

Terms Relating to Types of Screw Threads

Screw Thread—A screw thread (hereinafter referred to as a thread) is a ridge of uniform section in the form of a helix on the external or internal surface of a cylinder or in the form of a conical spiral on the external or internal surface of a cone or frustum of a cone. A thread formed on a cylinder is known as a *straight* or *parallel* thread, to distinguish it from a *taper* thread which is formed on a cone or frustum of a cone.

External Thread—An external thread is a thread on the external surface of a cylinder or cone.

Internal Thread—An internal thread is a thread on the internal surface of a hollow cylinder or cone.

Right-Hand Thread—A thread is a right-hand thread if, when viewed axially, it winds in a clockwise and receding direction.

Left-Hand Thread—A thread is a left-hand thread if, when viewed axially, it winds in a counterclockwise and receding direction. All left-hand threads are designated *LH*.

Single Thread—A single (single-start) thread is one having lead equal to the pitch.

Multiple Thread—A multiple (multiple-start) thread is one in which the lead is an integral multiple of the pitch.

Classes of Threads—Classes of threads are distinguished from each other by the amount of tolerance or tolerance and allowance specified.

Terms Relating to Size of Parts

Dimension—A dimension is a geometrical characteristic, such as a diameter, length, angle, circumference, or center distance, of which the size is specified.

Size—Size is a designation of magnitude.

Nominal Size—The nominal size is the designation which is used for the purpose of general identification.

Basic Size—The basic size of a dimension is the theoretical size from which the limits of size for that dimension are derived by the application of the allowance and tolerances.

Design Size—The design size of a dimension is the size in relation to which the limits of tolerance for that dimension are assigned.

Actual Size—The actual size of a dimension is the measured size of that dimension on an individual part.

Limits of Size—These limits are the maximum and minimum sizes permissible for a specific dimension.

Tolerance—The tolerance on a dimension is the total permissible variation in its size. The tolerance is the difference between the limits of size.

Allowance—An allowance is an intentional difference in correlated dimensions of mating parts. It is the minimum clearance (positive allowance) or maximum interference (negative allowance) between such parts.

Fit—The fit between two mating parts is the relationship existing between them with respect to the amount of clearance or interference which is present when they are assembled.

Terms Relating to Geometrical Elements of Screw Threads

Axis—The axis of a thread is the axis of its pitch cylinder or cone.

Pitch Line—The pitch line is a generator of the imaginary cylinder or cone specified in the definition of pitch diameter.

Form—The form of thread is its profile in an axial plane for a length of one pitch.

Basic Form of Thread—The basic form of a thread is the theoretical profile of the thread for a length of one pitch in an axial plane, on which the design forms of the threads for both the external and internal threads are based.

Design Form of Thread—The design forms for a thread are the maximum metal forms permitted for the external and internal threads.

Fundamental Triangle—The fundamental triangle is the triangle whose corners coincide with three consecutive intersections of the extended flanks of the basic form.

Flank—The flank (or side) of a thread is either surface connecting the crest with the root, the intersection of which, with an axial plane, is a straight line.

Leading Flank—The leading flank of a thread is the one which, when the thread is about to be assembled with a mating thread, faces the mating thread.

Following Flank—The following flank of a thread is the one which is opposite to the leading flank.

Pressure Flank—The pressure flank is that which takes the thrust or load in an assembly. The term is used particularly in relation to buttress and other similar threads.

Clearance (or Trailing) Flank—The clearance flank is that which does not take the thrust or load in an assembly.

Crest—The crest is that surface of the thread which joins the flanks of the thread and is farthest from the cylinder or cone from which the thread projects.

Root—The root is that surface of the thread which joins the flanks of adjacent thread forms and is identical with or immediately adjacent to the cylinder or cone from which the thread projects.

Sharp Crest (or Crest Apex)—The sharp crest is the apex formed by the intersection of the flanks of a thread when extended, if necessary, beyond the crest.

Sharp Root (or Root Apex)—The sharp root is the apex formed by the intersection of the flanks of adjacent thread forms when extended, if necessary, beyond the root.

Base—The base of a thread is that section of the thread which coincides with the cylinder or cone from which the thread projects.

Complete Thread—The complete (or full) thread is that part of the thread having full form at both crest and root. When there is a chamfer at the start of the thread, not exceeding two pitches in length, it is included within the length of complete thread.

Incomplete Thread—This is also known as the vanish or washout thread. On straight threads, the incomplete thread is that portion at the end having roots not fully formed by the lead or chamfer on threading tools.

Effective Thread—The effective (or useful) thread includes the complete thread and that portion of the incomplete thread having fully formed roots but having crests not fully formed.

Total Thread—The total thread includes the complete or effective thread and the incomplete thread.

Vanish Cone—The vanish cone is an imaginary cone, the surface of which would pass through the roots of the incomplete thread formed by the lead or chamfer of the threading tool.

Vanish Point—The vanish point of an external thread is the

intersection of a generator of the vanish cone with a generator of the cylinder of the largest major diameter of the thread.

Blunt Start—Blunt start designates the removal of the partial thread at the entering end of thread. This is a feature of threaded parts which are repeatedly assembled by hand, such as hose couplings and thread plug gages, to prevent cutting of hands and crossing of threads, and which was formerly known as a *Higbee cut.*

Terms Relating to Dimensions of Screw Threads

Terms relating to dimensions of both straight and taper threads are defined as follows:

Pitch—The pitch of a thread is the distance, measured parallel to its axis, between corresponding points on adjacent thread forms in the same axial plane and on the same side of the axis.

Lead—The lead is the distance a threaded part moves axially, with respect to a fixed mating part, in one complete rotation.

Threads Per Inch—The number of threads per inch is the reciprocal of the pitch in inches.

Turns Per Inch—The number of turns per inch is the reciprocal of the lead in inches.

Included Angle—The included angle of a thread (or angle of thread) is the angle between the flanks of the thread measured in an axial plane.

Flank Angle—The flank angles are the angles between the individual flanks and the perpendicular to the axis of the thread, measured in an axial plane. A flank angle of a symmetrical thread is commonly termed the half-angle of thread.

Lead Angle—On a straight thread the lead angle is the angle made by the helix of the thread at the pitch line with a plane perpendicular to the axis. On a taper thread, the lead angle at a given position is the angle made by the conical spiral of the thread at the pitch line with the plane perpendicular to the axis at that position.

Thickness—The thickness of thread is the distance between the flanks of the thread measured at a specified position and parallel to the axis.

Height of Fundamental Triangle—The height of the fundamental triangle of a thread, or the height of a sharp-V thread, is the distance, measured perpendicular to the axis, between the sharp major and minor cylinders or cones, respectively.

Height of Thread—The height (or depth) of thread is the distance, measured perpendicular to the axis, between the major and minor cylinders or cones, respectively.

Addendum—The addendum of an external thread is the distance, measured perpendicular to the axis, between the major and pitch cylinders or cones, respectively. The addendum of an internal thread is the distance, measured perpendicular to the axis, between the minor and pitch cylinders or cones, respectively.

Dedendum—The dedendum of an external thread is the distance, measured perpendicular to the axis, between the pitch and minor cylinders or cones, respectively. The dedendum of an internal thread is the distance, measured perpendicular to the axis, between the major and pitch cylinders or cones, respectively.

Crest Truncation—The crest truncation of a thread is the distance, measured perpendicular to the axis, between the sharp crest (or crest apex) and the cylinder or cone which bounds the crest.

Root Truncation—The root truncation of a thread is the distance, measured perpendicular to the axis, between the sharp root (or root apex) and the cylinder or cone which bounds the root.

Major Diameter—On a straight thread, the major diameter is the diameter of the imaginary coaxial cylinder which bounds the crest of an external thread or the root of an internal thread.

On a taper thread, the major diameter, at a given position on the thread axis, is the diameter of the major cone at that position.

Minor Diameter—On a straight thread, the minor diameter is the diameter of the imaginary coaxial cylinder which bounds the root of an external thread or the crest of an internal thread.

On a taper thread, the minor diameter, at a given position on the thread axis, is the diameter of the minor cone at that position.

Pitch Diameter (*Simple Effective Diameter*)—On a straight thread, the pitch diameter is the diameter of the imaginary coaxial cylinder, the surface of which would pass through the thread profiles at such points as to make the width of the groove equal to one-half of the basic pitch. On a perfect thread this occurs at the point where the widths of the thread and groove are equal.

On a taper thread, the pitch diameter at a given position on the thread axis is the diameter of the pitch cone at that position.

Effective Size (*or Virtual Effective Diameter*)—The effective size of an external or internal thread is the diameter derived by adding to the pitch diameter in the case of an external thread, or subtracting from the pitch diameter in the case of an internal thread, the cumulative effects of pitch and angle errors.

Depth of Thread Engagement—The depth of thread engagement between two mating threads is the distance, measured perpendicular to the axis, by which their thread forms overlap each other.

Length of Thread Engagement—The length of thread engagement of two mating threads is the distance between the extreme points of contact on the pitch cylinders or cones, measured parallel to the axis.

Crest Clearance—The crest clearance in a thread assembly is the distance, measured perpendicular to the axis, between the crest of a thread and the root of its mating thread.

Stress Area—The stress area is the assumed area of an externally threaded part which is used for the purpose of computing the tensile strength.

Tabulated stress areas applicable to steel parts are computed from the following formula:

$$A_s = 3.1416\left(\frac{E_m + K_m}{4}\right)^2$$

where A_s = stress area
E_m = mean pitch diameter, Class 3 tolerances
K_m = mean minor diameter, Class 3 tolerances

A formula giving results within ½% for computing Unified-form stress areas that are not tabulated is:

$$A_s = 3.1416\left(\frac{E}{2} - \frac{H}{6}\right)^2$$

where E = basic pitch diameter

For $\frac{H}{6}$, see Table 1.

(*Text continued after Fig. 4.*)

General Symbols

SYMBOLS	DIMENSIONS	REMARKS
D	Major diameter	Exception: B is used for basic major diameter when this differs from the nominal major diameter. Subscripts s or n, indicating external or internal thread, may be used if necessary.
E	Pitch diameter	Subscripts s or n, indicating external or internal thread, may be used if necessary.
K	Minor diameter	
p	Pitch	Equals $1/n$.
l	Lead	Equals $1/N$.
n	Number of threads per unit of length (per inch)	
N	Number of turns per unit of length (per inch)	
H	Height of fundamental triangle	
h	Height (or depth) of thread	Subscripts s or n, indicating external or internal thread, may be used if necessary.
h_a	Addendum	
h_d	Dedendum	
h_b	Equals $2h_a$ of basic external thread	
h_e	Depth of thread engagement	
a	Half-angle of symmetrical thread	
a_1	Angle between leading flank of thread and normal to axis of thread	
a_2	Angle between following flank of thread and normal to axis of thread	
λ	Lead angle	Tan $\lambda = \dfrac{l}{\pi E}$
r	Radius of rounding at crest, or radius of rounding at root	Subscripts c or r, indicating crest or root; and s or n, indicating external or internal thread, may be used if necessary.
	Distance from apex of fundamental triangle to adjacent root or crest of thread:	
s	If rounded	
f	If flat	

SYMBOLS	DIMENSIONS	REMARKS
	Distance from apex of fundamental triangle to:	
f_{cs}	Flat at crest of external thread	
f_{rs}	Flat at root of external thread	
f_{cn}	Flat at crest of internal thread	
f_{rn}	Flat at root of internal thread	
	Width of:	
F	Flat (general)	
F_{cs}	Flat at crest of external thread	
F_{rs}	Flat at root of external thread	
F_{cn}	Flat at crest of internal thread	
F_{rn}	Flat at root of internal thread	
L	Length of bolt or screw	
L_t	Length of full thread	Subscripts s or n, indicating external or internal thread, may be used if necessary.
L_e	Length of thread engagement	
w	Diameter of measuring wires	
M_w	Measurement over wires	
T	Measurement under wires	
C	Correction to measurement over wires to give pitch diameter	$E = M_w - C - c$. $C = w\,(1 + \text{cosec } a) - (\cot a)/2n$.
P	Correction to measurement under wires to give pitch diameter	$E = T + P - c$. $P = 1/2p \cot a - (\text{cosec } a - 1)\,w$.
λ_1	Wire angle	
c	Wire angle correction	See National Physical Laboratory "Notes on Screw Gages", August, 1944, page 23; or National Bureau of Standards Handbook H28 (1944), page 228.
prefix δ with symbol	Error in any dimension	Examples: Error in pitch, δp; error in half-angle, δa_1 or δa_2.
ΔE_a	Pitch-diameter equivalent of errors in flank angles	
ΔE_p	Pitch-diameter equivalent of error in pitch	
G	Allowance at pitch diameter	

Greek Alphabet

A α Alpha	Δ δ Delta	H η Eta	K κ Kappa	N ν Nu	Π π Pi	T τ Tau	X χ Chi
B β Beta	E ϵ Epsilon	Θ θ Theta	Λ λ Lambda	Ξ ξ Xi	P ρ Rho	Υ υ Upsilon	Ψ ψ Psi
Γ γ Gamma	Z ζ Zeta	I ι Iota	M μ Mu	O o Omicron	Σ σ Sigma	Φ ϕ Phi	Ω ω Omega

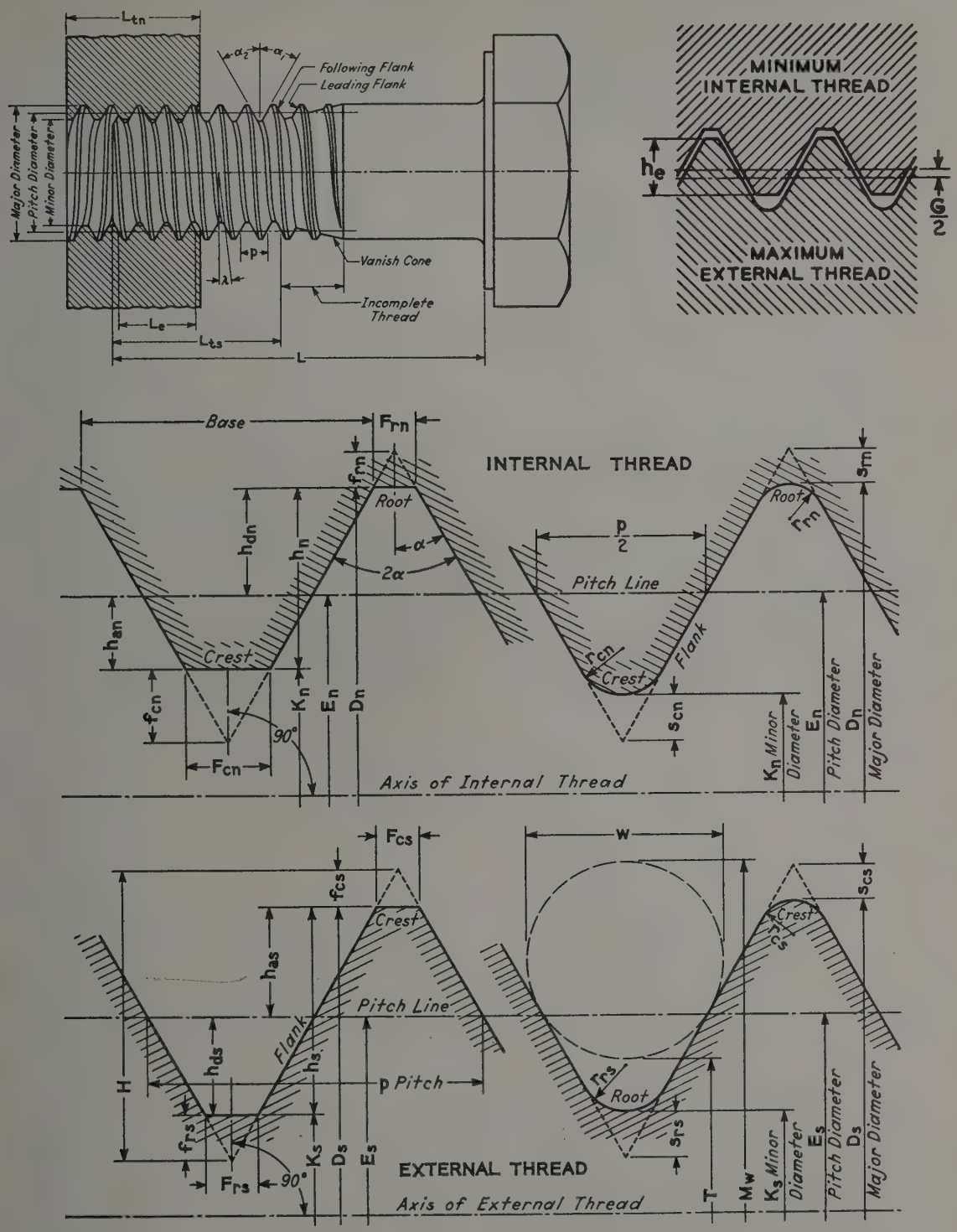


FIG. 4—TERMINOLOGY AND SYMBOLS
(These drawings are not intended to illustrate thread forms but application of symbols only.)

Thread Shear Area—The thread shear area of the external thread is the effective area at a diameter equal to the maximum minor diameter of the internal thread. The thread shear area of the internal thread is the effective area at a diameter equal to the minimum major diameter of the external thread. The formula for shear area of the external threads at a diameter equal to the maximum minor diameter of the internal thread (AS_s) is as follows:

$$AS_s = 3.1416nL_eK_n \max\left[\frac{1}{2n} + 0.57735(E_s \min - K_n \max)\right]$$

The formula for shear area of the internal threads at a diameter equal to the minimum major diameter of external threads (AS_n) is as follows:

$$AS_n = 3.1416nL_eD_s \min\left[\frac{1}{2n} + 0.57735(D_s \min - E_n \max)\right]$$

where n = number of threads per inch
L_e = length of engagement
K_n max = maximum minor diameter of internal thread
E_s min = minimum pitch diameter of external thread
D_s min = minimum major diameter of external thread
E_n max = maximum pitch diameter of internal thread

As materials bearing the same name vary greatly in ultimate strength and in other essential characteristics, the formulas given below are included in order that a safe length of external thread mating with internal threads may be calculated. It is desirable that the length of internal thread and the dimensions of this thread, particularly its minor diameter, be such that, taking into account a possible difference in strength of material of the internal and external threads, the threaded portion of the external thread will break before either the external or internal threads strip. For this reason, the shearing strength of the assembled unit should be taken as ½ the tensile strength, which gives a small factor of safety.

The length of engagement of threaded unit which will develop maximum strength of an assembled threaded unit with external and internal thread manufactured of materials of equal tensile strength is computed from the following formula:

$$L_e = \frac{2 \times \text{Stress Area}}{3.1416nK_n \max\left[\frac{1}{2n} + 0.57735(E_s \min - K_n \max)\right]}$$

This formula has the factor "½" for relation of shearing strength to tensile strength incorporated therein. The formula, while given for steel external and internal threads, may be used for brass external and internal threads and provide additional safety factor.

Where the external and internal threads are manufactured of materials of different tensile strength, the factor J for the relative strength in shear of external threads with respect to internal threads must be considered. The factor J is computed from the following formula:

$$J = \frac{AS_s \times \text{Tensile Strength of External Thread}}{AS_n \times \text{Tensile Strength of Internal Thread}}$$

The length of engagement of threaded unit adjusted to obtain proper relation of strength to cause breakage of bolt before threads will shear is Q and is computed from the following formulas:

If J is less than 1, $Q = L_e$
If J is greater than 1, $Q = J \times L_e$

(*Continued on next page.*)

Appendix B—Formulas for Standard Thread Series, Limits of Size

UNC, UNF, NC, NF, NEF, 8N, 12N, and 16N Series
Classes 1A, 2A, 3A, 1B, 2B, 3B, 2, and 3

External Thread

Where D = basic major (nominal) diameter
h_s = thread height (see SAE Table 1)
h_{as} = screw addendum height (see SAE Table 1)
$h_b = 2h_{as}$ (see SAE Table 1)
E = basic pitch diameter (D minus h_b) (see SAE Table 1)
K_s = minor diameter (D minus $2h_s$) (see SAE Table 1)
p = pitch (in inches)

Maximum Major Diameter

Classes 1A and 2A = Basic major diameter (D), minus allowance (see SAE Table 21)
Classes 3A, 2, and 3 = Basic major diameter (D)

Minimum Major Diameter

Class 1A = Maximum, minus $0.090\sqrt[3]{p^2}$ (see SAE Table 9)
Classes 2A[7] and 3A = Maximum, minus $0.060\sqrt[3]{p^2}$ (see SAE Tables 10, 11, and 17)
Classes 2 and 3 = Maximum, minus two times Class 2 pitch-diameter tolerance NC and NF series (see SAE Tables 15, 16, and 19)

Maximum Pitch Diameter

Classes 1A and 2A = Basic pitch diameter (E), minus allowance (see SAE Tables 9, 10, and 17)
Classes 3A, 2, and 3 = Basic pitch diameter (E)

Minimum Pitch Diameter

= Maximum, minus tolerance for class of thread specified (see SAE Tables 9 to 20)

Maximum Minor Diameter

Classes 1A and 2A
To intersection of rounded root with its centerline (see Fig. 1)
= Minor diameter (K_s), minus allowance (see SAE Tables 9, 10, and 17)
To intersection of rounded root with flanks of threads
= Minor diameter (K_s) (see SAE Table 1), minus allowance, plus $H/6$ (see SAE Tables 9, 10, and 17)

Classes 3A, 2, and 3
To intersection of rounded root with its centerline (see Fig. 1)
= Minor diameter (K_s) (see SAE Table 1)
To intersection of rounded root with flanks of threads
= Minor diameter (K_s) plus $H/6$

Minimum Minor Diameter

In dimensioning external threads, the minimum minor diameter is not specified, being established by the crest of an unworn tool. In practice, the minor diameter of an external thread is satisfactory when accepted by a gage or gaging method that represents the maximum metal condition of the internal thread.

Internal Thread

Where D = basic major (nominal) diameter
h_n = thread height (see SAE Table 1)
E = basic pitch diameter (D minus h_b) (see SAE Table 1)
K_n = minor diameter (D minus $2h_n$) (see SAE Table 1)
p = pitch (in inches)

Maximum Major Diameter

In dimensioning internal threads the maximum major diameter is not specified, being established by the crest of an unworn tool. In practice, the major diameter of an internal thread is satisfactory when accepted by a gage or gaging method that represents the maximum metal condition of an external thread which has no allowance.

Minimum Major Diameter

= Basic major diameter (D)

Minimum Pitch Diameter

= Basic pitch diameter (E)

Maximum Pitch Diameter

= Minimum, plus tolerance for class of thread specified (see SAE Tables 12 to 16, 18 to 20)

Minimum Minor Diameter

= Minor diameter (K_n)

Maximum Minor Diameter

= Minimum, plus tolerance (see SAE Tables 12 to 16, 18 to 20)

Appendix C—Formulas for Standard Thread Series, Allowances and Tolerances

UNC, UNF, NC, NF, NEF, 8N, 12N, and 16N Series
Classes 1A, 2A, 3A, 1B, 2B, 3B, 2, and 3

External Thread

Where D = basic major (nominal) diameter
h_s = thread height (see SAE Table 1)
L_e = length of engagement (in inches)
p = pitch (in inches)

[7] Exceptions are the coarse-thread and 8-thread series Class 2A, unfinished hot-rolled material, which take the Class 1A formula.

Allowance

Classes 1A and 2A = 30% of Class 2A pitch-diameter tolerance (see SAE Tables 9, 10, 17, and 22)
Classes 3A, 2, and 3 = No allowance

Major-Diameter Tolerance

Class 1A = $0.090\sqrt[3]{p^2}$
Classes 2A, semi-finished and finished, and 3A = $0.060\sqrt[3]{p^2}$
Class 2A UNC unfinished hot-rolled material = $0.090\sqrt[3]{p^2}$

Class 2 NC unfinished hot-rolled material = No formula[8] (see SAE Table 10, footnote e)

Classes 2 and 3, semi-finished and finished = Two times Class 2 pitch-diameter tolerance, NC and NF series for threads per inch specified (see SAE Tables 15 and 19, and Table 15, footnote b)

Pitch-Diameter Tolerance

UNC, UNF, NC and NF Series

Class 1A = 1.500 Class 2A pitch-diameter tolerance

[9] Class 2A = $0.0015\sqrt[3]{D} + 0.0015\sqrt{L_e} + 0.015\sqrt[3]{p^2}$

Class 3A = 0.750 Class 2A pitch-diameter tolerance

Classes 2 and 3 = No formulas (see SAE Tables 15, 16, 19, and 20)

Values in these tables for Class 2A are based on the above formula, with $L_e = D$. For Classes 2 and 3, they are based on the pitch of the thread only and are correct for a length of engagement equal to the nominal diameter but may be used for lengths of engagement up to $1\frac{1}{2}$ D. For lengths of engagement greater than $1\frac{1}{2}$ D, use values obtained from SAE Tables 18 to 26, 29, and 30.

NEF Series

[9] Class 2A = $0.0015\sqrt[3]{D} + 0.0015\sqrt{L_e} + 0.015\sqrt[3]{p^2}$

[9] Class 2 = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$

Class 3 = 70% of Class 2 pitch-diameter tolerance

Values in SAE Tables 17, 19, and 20 for Classes 2A, 2, and 3 are based on a length of engagement (L_e) equal to 9 threads. These values are suitable for lengths of engagement of from 5 to 15 pitches. For greater lengths of engagement, use values obtained from SAE Tables 24, 29, and 30.

8N Series

[9] Class 2A = $0.0015\sqrt[3]{D} + 0.0015\sqrt{L_e} + 0.015\sqrt[3]{p^2}$

[9] Class 2 = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$

Class 3 = 70% of Class 2 pitch-diameter tolerance

Values in SAE Tables 17, 19, and 20 are based on a length of engagement (L_e) equal to the nominal diameter for Class 2A and for Classes 2 and 3 up to and including 3 in. diameter; for larger diameters of Classes 2 and 3 they are based on a length of engagement of 3 in.

These values, or those given in SAE Table 17 which are based on 9 threads length of engagement, are suitable for shorter lengths of engagement. For lengths of engagement greater than the above, use values obtained from SAE Tables 24, 29, and 30.

12N Series

[9] Class 2A = $0.0015\sqrt[3]{D} + 0.0015\sqrt{L_e} + 0.015\sqrt[3]{p^2}$

[9] Class 2 = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$

Class 3 = 70% of Class 2 pitch-diameter tolerance

Values in SAE Tables 17, 19, and 20 for Classes 2A, 2, and 3 are based on a length of engagement (L_e) equal to 9 threads except for those sizes which are in the UNC or UNF thread series. These values are suitable for lengths of engagement of from $5p$ to $15p$. For greater lengths of engagement, use values obtained from SAE Tables 24, 29, and 30.

16N Series

[9] Class 2A = $0.0015\sqrt[3]{D} + 0.0015\sqrt{L_e} + 0.015\sqrt[3]{p^2}$

Class 2

$\frac{3}{4}$ in. size = $\frac{3}{4}$ in.—16UNF pitch-diameter tolerance

[9] Over $\frac{3}{4}$ in. = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$

Class 3 = 70% of Class 2 pitch-diameter tolerance

Values in SAE Tables 17, 19, and 20 for Classes 2A, 2, and 3 are based on a length of engagement (L_e) equal to the nominal diameter for the $\frac{3}{4}$ in. size and a length of engagement of 9 threads for larger sizes. These values are suitable for lengths of engagement of from $5p$ to $15p$. For greater lengths of engagement use values obtained from SAE Tables 24, 29, and 30.

Minor-Diameter Tolerance

Classes 1A, 2A, 3A, 2, and 3

To intersection of rounded root with its centerline = Pitch-diameter tolerance for class of thread specified, plus $H/12$ (½ of $H/6$) (see SAE Table 1)

To intersection of rounded root with flanks of threads = Pitch-diameter tolerance for class of thread specified, plus $H/4$ (see SAE Table 1)

The tolerance for minor diameter is for reference only. In dimensioning external threads the minimum minor diameter is not specified, being established by the crest of an unworn tool. In practice, the minor diameter of an external thread is satisfactory when accepted by a gage or gaging method that represents the maximum metal condition of the internal thread.

Internal Thread

Where D = basic major (nominal) diameter
h_n = thread height (see SAE Table 1)
L_e = length of engagement (in inches)
p = pitch (in inches)

Major-Diameter Tolerance

Classes 1B, 2B, 3B, 2 and 3 = $H/6$ (see SAE Table 1)

The tolerance for major diameter is for reference only. In dimensioning internal threads the maximum major diameter is not specified, being established by the crest of an unworn tool. In practice, the major diameter of an internal thread is satisfactory when accepted by a gage or gaging method that represents the maximum metal condition of an external thread which has no allowance.

Pitch-Diameter Tolerance

UNC, UNF, NC, and NF Series

Class 1B = 1.950 Class 2A pitch-diameter tolerance (1.500 Class 2B)

Class 2B = 1.30 Class 2A pitch-diameter tolerance

Class 3B = 0.975 Class 2A pitch-diameter tolerance (0.750 Class 2B)

Classes 2 and 3 = No formulas (see SAE Tables 15, 16, 19, and 20)

Values in these tables for Classes 2 and 3 are based on

[8] Two times Class 1 pitch-diameter tolerance, NC series for threads per inch specified.

[9] See Tables 33 and 34 (Appendix F) for values of these terms corresponding to given values of diameter, length of engagement, and pitch.

the pitch of the thread only and are correct for a length of engagement equal to the nominal diameter but may be used for any lengths of engagement up to $1\frac{1}{2}D$. For greater lengths of engagement, use values obtained from SAE Tables 26 to 30.

NEF Series

Class 2B = 1.300 Class 2A pitch-diameter tolerance

Class 2 = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$

Class 3 = 70% Class 2 pitch-diameter tolerance

Values in SAE Tables 18 to 20 for Classes 2B, 2, and 3 are based on a length of engagement (L_e) of 9 threads.

8N Series

Class 2B = 1.300 Class 2A pitch-diameter tolerance

Class 2 = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$

Class 3 = 70% of Class 2 pitch-diameter tolerance

Values in SAE Tables 18 to 20 are based on a length of engagement (L_e) equal to the nominal diameter for Class 2B and for Classes 2 and 3 up to and including 3 in. diameter; for larger diameters of Classes 2 and 3 they are based on a length of engagement of 3 in.

These values, based on $9p$ length of engagement, are suitable for shorter lengths of engagement. For greater lengths of engagement, use values obtained from SAE Tables 27, 29, and 30.

12N Series

Class 2B = 1.300 Class 2A pitch-diameter tolerances

Class 2 = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$

Class 3 = 70% of Class 2 pitch-diameter tolerance

Values in SAE Tables 18 to 20 for Classes 2B, 2, and 3 are based on a length of engagement (L_e) equal to 9 threads except for those sizes which are in the UNC or UNF thread series. These values are suitable for lengths of engagement of from $5p$ to $15p$. For greater lengths of engagement use values obtained from SAE Tables 27, 29, and 30.

16N Series

Class 2B = 1.300 Class 2A pitch-diameter tolerance

Class 2

$\frac{3}{4}$ in. size = $\frac{3}{4}$ in.—16 UNF pitch-diameter tolerance

Over $\frac{3}{4}$ in. = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$

Class 3 = 70% of Class 2 pitch-diameter tolerance

Values in SAE Table 18 to 20 for Classes 2B, 2, and 3 are based on a length of engagement (L_e) equal to the nominal diameter for the $\frac{3}{4}$ in. size and a length of engagement of 9 threads for larger sizes. These values are suitable for lengths of engagement of from $5p$ to $15p$. For greater lengths of engagement, use values obtained from SAE Tables 27, 29, and 30.

Minor-Diameter Tolerance

Classes 1B, 2B, and 3B, all thread series = $0.05\sqrt[3]{p^2} + 0.03p/D - 0.002$ in., within the following limitations:

Tolerance shall not be greater than $0.394p$. (This corresponds to 53% of the basic thread height and applies in the range of the smallest numbered sizes of the UNC, UNF, NC, and NF thread series.)

Tolerance shall not be less than:

For 80 to 13 threads per inch, inclusive, $0.23p - 1.5p^4$ (This corresponds to a thread height of 67% for 80 threads per inch, graduating to 74% for 13 threads per inch.)

For 12 threads per inch and coarser, $0.120p$. (This corresponds to a thread height of 74% and is the tolerance for all sizes 12 threads and coarser and 1 in. and larger.) See SAE Tables 12 to 20.

NC Number Sizes

Classes 2 and 3 = $[1.08253 - 1.299(\sqrt[3]{D - 2p} + 0.160)]p$

NF Number Sizes

Classes 2 and 3 = $[1.08253 - 1.299(\sqrt[3]{D - 2p} + 0.180)]p$

NC Fractional Sizes

Classes 2 and 3

No. 12 to 1 in., inclusive, No formulas (see SAE Tables 15 and 16)

Over 1 in. = $(1.08253 - 0.97428)p$

NF Fractional Sizes

Classes 2 and 3

$\frac{1}{4}$ in. to 1 in., inclusive, No formulas (see SAE Tables 15 and 16)

Over 1 in. = $(1.08253 - 0.97428)p$

NEF Series

Classes 2 and 3, No formulas (see SAE Tables 19 and 20)

8N Series

Classes 2 and 3 = 1 in.—8NC minor-diameter tolerance (see SAE Tables 19 and 20)

12N Series

Classes 2 and 3

$\frac{1}{2}$ in. and 9/16 in. sizes = 9/16 in.—12 NC minor-diameter tolerance (see SAE Tables 19 and 20)

Over 9/16 in. = $(1.08253 - 0.97428)p$

16N Series

Classes 2 and 3 = $\frac{3}{4}$ in.—16 NF minor-diameter tolerance (see SAE Tables 19 and 20)

In the above formulas,

$1.299p$ = double depth of American National Thread

$1.08253p$ = $83\frac{1}{3}$% of double depth

D = major diameter

$2p$ = 2 pitches or threads

(see SAE Tables 12 to 20)

Appendix D—Formulas for Special Threads, Limits of Size

Classes 1A, 2A, 3A, 1B, 2B, 3B, 2, and 3

External Thread

Where D = basic major (nominal) diameter

h_s = thread height (see SAE Table 1)

E = basic pitch diameter ($D - h_b$)

K_s = minor diameter ($D - 2h_s$)

p = pitch (in inches)

Maximum Major Diameter

Classes 1A and 2A = Basic major diameter (D), minus allowance (see SAE Table 22 or formula for allowance, Appendix E)

Classes 3A, 2, and 3 = Basic major diameter (D)

(*Continued on next page.*)

Minimum Major Diameter

Class 1A = Maximum, minus $0.090\sqrt[3]{p^2}$ (see SAE Table 21)
Classes 2A and 3A = Maximum, minus $0.060\sqrt[3]{p^2}$ (see SAE Table 21)
Classes 2 and 3 = Maximum, minus two times Class 2 pitch-diameter tolerance NC and NF series (see SAE Table 21), or minus the special-thread pitch-diameter tolerance for class of thread specified (see formulas, Appendix E), whichever gives the smaller limiting value.

Maximum Pitch Diameter

Classes 1A and 2A = Basic pitch diameter (E), minus allowance (see SAE Table 22)
Classes 3A, 2, and 3 = Basic pitch diameter (E)

Minimum Pitch Diameter

All Classes = Maximum, minus pitch-diameter tolerance for respective class of thread (see formulas, Appendix E)

Maximum Minor Diameter

Classes 1A and 2A
To intersection of rounded root with its centerline (see Fig. 1)
= Basic minor diameter (K_s), minus allowance (see SAE Table 22)
To intersection of rounded root with flanks of threads
= Minor diameter (K_s), minus allowance, (see SAE Tables 1 and 22) plus $H/6$
Classes 3A, 2, and 3
To intersection of rounded root with its centerline (see Fig. 1)
= Minor diameter (K_s)
To intersection of rounded root with flanks of threads
= Minor diameter (K_s), plus $H/6$

Minimum Minor Diameter

In dimensioning external threads the minimum minor diameter is not specified, being established by the crest of an unworn tool. In practice, the minor diameter of an external thread is satisfactory when accepted by a gage or gaging method that represents the maximum metal condition of the internal thread.

Internal Thread

Where D = basic major (nominal) diameter
h_n = thread height (see SAE Table 1)
E = basic pitch diameter ($D - h_s$)
K_n = minor diameter ($D - 2h_n$)
p = pitch (in inches)

Maximum Major Diameter

In dimensioning internal threads the maximum major diameter is not specified, being established by the crest of an unworn tool. In practice, the major diameter of an internal thread is satisfactory when accepted by a gage or gaging method that represents the maximum metal condition of the external thread which has no allowance.

Minimum Major Diameter

= Basic major diameter (D)

Minimum Pitch Diameter

= Basic pitch diameter (E)

Maximum Pitch Diameter

= Minimum, plus pitch-diameter tolerance for class of thread specified (see formulas, Appendix E)

Minimum Minor Diameter

= Minor diameter (K_n)

Maximum Minor Diameter

= Minimum, plus minor-diameter tolerance from SAE Table 31 or 32, or plus the pitch-diameter tolerance (see formulas, Appendix E), whichever gives the larger value.

Limitations of Design

Some combinations of diameter, pitch, and length of engagement are impractical from a production or assembly standpoint.

In production, it is considered impractical to tap a thread unless its diameter is greater than six times the thread height; therefore, when the ratio of D to $\frac{3}{4}H$ is less than 6, the use of a larger diameter, a finer pitch of thread, or both, should be considered.

In assembly and use, the combined tolerances and allowances on both mating parts should not allow threads to disengage on one side when assembly is eccentric. The minimum amount of overlap is arbitrary and controversial but the following general rule can be used in lieu of more specific data:

As the first step to assure the minimum safe overlap on both sides when the assembly is concentric, the difference between the minimum major diameter of the external thread and the maximum minor diameter of the internal thread should not be less than twice the addendum of the external thread ($\frac{3}{4}H$, SAE Table 1). (Otherwise stated, the sum of the major-diameter tolerance and allowance, if any, of the external thread and the minor-diameter tolerance of the internal thread should not be greater than 4/3 the addendum of the external thread, $H/2$, SAE Table 1.) This provides for a minimum of 50% thread engagement. As the second step to assure the minimum safe overlap on one side when the assembly is eccentric, the difference between the maximum pitch diameter of the internal thread and the minimum pitch diameter of the external thread should not be greater than twice the addendum of the external thread ($\frac{3}{4}H$, SAE Table 1). (Otherwise stated, the sum of the pitch-diameter tolerances of both threads and the allowance, if any, should not be greater than twice the addendum of the external thread, $\frac{3}{4}H$, SAE Table 1.) This provides for an eccentric assembly condition equal to the addendum of external thread ($\frac{3}{8}H$, SAE Table 1) and zero minimum overlap on one side. If the results from the limiting dimensions selected violate the above rules, the tolerances should be reduced by using a closer class of tolerance, assuming tolerances consistent with manufacturing possibility, or a coarser pitch should be used to increase the amount of overlap. The major-diameter tolerance of the external thread or minor-diameter tolerance of the internal thread should not be less than the pitch-diameter tolerance of the respective thread to maintain thread form.

(*Continued on next page.*)

Appendix E—Formulas for Special Threads, Allowances and Tolerances

Classes 1A, 2A, 3A, 1B, 2B, 3B, 2, and 3

External Thread

Where D = basic major (nominal) diameter
h_s = thread height (see SAE Table 1)
L_e = length of engagement (in inches)
p = pitch (in inches)

Allowance

Classes 1A and 2A = 0.300 Class 2A pitch-diameter tolerance
Classes 3A, 2, and 3 = No allowance

Major-Diameter Tolerance

Class 1A = $0.090\sqrt[3]{p^2}$ (see SAE Table 21)
Classes 2A and 3A = $0.060\sqrt[3]{p^2}$ (see SAE Table 21)
Classes 2 and 3 = Two times Class 2 pitch-diameter tolerance NC and NF series (see SAE Table 15), or the special-thread pitch-diameter tolerance (see formulas immediately following) for class of thread specified, whichever is the larger value.

Pitch-Diameter Tolerance

Class 1A = 1.500 Class 2A pitch-diameter tolerance
[10]Class 2A = $0.0015\sqrt[3]{D} + 0.0015\sqrt{L_e} + 0.015\sqrt[3]{p^2}$
Class 3A = 0.750 Class 2A pitch-diameter tolerance
[10]Class 2 = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$
Class 3 = 70% of Class 2 pitch-diameter tolerance

Minor-Diameter Tolerance

Classes 1A, 2A, 3A, 2, and 3
To intersection of rounded root with its centerline
= Pitch-diameter tolerance for class of thread specified, plus $H/12$
To intersection of rounded root with flanks of threads
= Pitch-diameter tolerance for class of thread specified, plus $H/4$ (see SAE Table 1)

The tolerance for minor diameter is for reference only. In dimensioning external threads the minimum minor diameter is not specified, being established by the crest of an unworn tool. In practice, the minor diameter of an external thread is satisfactory when accepted by a gage or gaging method that represents the maximum metal condition of the internal thread.

Internal Thread

Where D = basic major (nominal) diameter
h_n = thread height (see SAE Table 1)
L_e = length of engagement (in inches)
p = pitch (in inches)

Major-Diameter Tolerance

Classes 1B, 2B, 3B, 2, and 3 = $H/6$ (see SAE Table 1)
The tolerance for major diameter is for reference only. In dimensioning internal threads the maximum major diameter is not specified, being established by the crest of an unworn tool. In practice, the major diameter of an internal thread is satisfactory when accepted by a gage or gaging method that represents the maximum metal condition of an external thread which has no allowance.

Pitch-Diameter Tolerance

Class 1B = 1.950 Class 2A pitch-diameter tolerance (1.5 Class 2B)
Class 2B = 1.300 Class 2A pitch-diameter tolerance
Class 3B = 0.975 Class 2A pitch-diameter tolerance (0.750 Class 2B)
[11]Class 2 = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$
Class 3 = 70% of Class 2 pitch-diameter tolerance

Minor-Diameter Tolerance

Classes 1B, 2B, and 3B = Tolerances derived from formulas for minor-diameter tolerance of standard internal threads (see Appendix C and SAE Table 31), or the pitch-diameter tolerance, whichever is the greater value.
Classes 2 and 3 = Tolerances derived from formulas for minor-diameter tolerance of standard internal threads (see Appendix C), or taken from SAE Table 32, or the pitch-diameter tolerance, whichever is the greatest value.

[10] See Tables 33 and 34 (Appendix F) for values of these terms corresponding to given values of diameter, length of engagement, and pitch.
[11] See Table 34 (Appendix F) for values of these terms corresponding to given values of diameter, length of engagement, and pitch.

Appendix F

TABLE 33—*Class 2A*,[a] *Increments in Pitch-Diameter Tolerance*[b]

DIAMETER						LENGTH OF ENGAGEMENT														PITCH	
						Based on					Based on				Based on				Based on				
D	$0.0015\sqrt[3]{D}$	D	$0.0015\sqrt[3]{D}$	D	$0.0015\sqrt[3]{D}$	1 D for sizes	9 for tpi	20 for tpi	L_e	$0.0015\sqrt{L_e}$	1 D for sizes	9 for tpi	20 for tip	L_e	$0.0015\sqrt{L_e}$	1 D for sizes	9 for tpi	20 for tpi	L_e	$0.0015\sqrt{L_e}$	1 D for sizes	9 for tpi	20 for tpi	L_e	$0.0015\sqrt{L_e}$	Threads per inch	$0.015\sqrt[3]{p^2}$
0.0600	0.000587	1.3125	0.001642	3.8750	0.002356	#0	—	—	0.0600	0.000367	—	28	—	0.3214	0.000850	1¼	—	16	1.2500	0.001677	4¼	—	—	4.2500	0.003092	80	0.000808
0.0625	0.000595	1.3750	0.001668	4.0000	0.002381	—	—	—	0.0625	0.000375	—	—	—	0.3281	0.000859	—	7	—	1.2857	0.001701	—	—	—	4.3750	0.003137	72	0.000867
0.0730	0.000627	1.4375	0.001693	4.2500	0.002430	#1	—	—	0.0730	0.000405	—	—	—	0.3438	0.000880	—	—	—	1.3125	0.001718	4½	—	—	4.5000	0.003182	64	0.000938
0.0860	0.000662	1.5000	0.001717	4.5000	0.002476	—	—	—	0.0781	0.000419	—	—	56	0.3571	0.000896	1⅜	—	—	1.3750	0.001759	—	—	—	4.6250	0.003226	56	0.001025
0.0938	0.000682	1.5625	0.001741	4.7500	0.002521	#2	—	—	0.0860	0.000440	—	—	—	0.3594	0.000899	—	—	14	1.4286	0.001793	4¾	—	—	4.7500	0.003269	48	0.001136
0.0990	0.000694	1.6250	0.001764	5.0000	0.002565	—	—	—	0.0938	0.000459	⅜	24	—	0.3750	0.000919	—	—	—	1.4375	0.001798	—	—	—	4.8750	0.003312	44	0.001204
0.1120	0.000723	1.6875	0.001786	5.2500	0.002607	#3	—	—	0.0990	0.000472	—	—	—	0.3906	0.000937	1½	6	—	1.5000	0.001837	5	—	4	5.0000	0.003354	40	0.001282
0.1250	0.000750	1.7500	0.001808	5.5000	0.002648	—	—	—	0.1094	0.000496	—	—	—	0.4063	0.000956	1⅝	—	—	1.6250	0.001912	—	—	—	5.1250	0.003396	36	0.001376
0.1380	0.000775	1.8125	0.001829	5.7500	0.002687	#4	—	—	0.1120	0.000502	—	—	48	0.4167	0.000968	—	—	12	1.6667	0.001936	5¼	—	—	5.2500	0.003437	32	0.001488
0.1640	0.000821	1.8750	0.001850	6.0000	0.002726	—	80	—	0.1125	0.000503	—	—	—	0.4219	0.000974	1¾	—	—	1.7500	0.001984	—	—	—	5.3750	0.003478	28	0.001627
0.1875	0.000859	1.9375	0.001870	7.0000	0.002869	#5	72	—	0.1250	0.000530	7/16	—	—	0.4375	0.000992	1⅞	—	—	1.8750	0.002054	5½	—	—	5.5000	0.003518	24	0.001803
0.1900	0.000862	2.0000	0.001890	8.0000	0.003000	#6	—	—	0.1380	0.000557	—	20	—	0.4500	0.001006	2	—	10	2.0000	0.002121	—	—	—	5.6250	0.003558	20	0.002036
0.2160	0.000900	2.0625	0.001909	9.0000	0.003120	—	64	—	0.1406	0.000562	½	18	40	0.5000	0.001061	2⅛	—	—	2.1250	0.002187	5¾	—	—	5.7500	0.003597	18	0.002184
0.2500	0.000945	2.1250	0.001928	10.0000	0.003232	—	—	—	0.1563	0.000593	—	—	36	0.5556	0.001118	2¼	4	—	2.2500	0.002250	—	—	—	5.8750	0.003636	16	0.002362
0.3125	0.001018	2.1875	0.001947	12.0000	0.003434	—	56	—	0.1607	0.000601	9/16	16	—	0.5625	0.001125	—	—	—	2.3750	0.002312	6	—	—	6.0000	0.003674	14	0.002582
0.3750	0.001082	2.2500	0.001966	14.0000	0.003615	#8	—	—	0.1640	0.000607	⅝	—	32	0.6250	0.001186	2½	—	8	2.5000	0.002372	—	—	—	6.5000	0.003824	13	0.002713
0.4375	0.001139	2.3125	0.001984	16.0000	0.003780	—	—	—	0.1719	0.000622	—	14	—	0.6429	0.001203	—	—	—	2.6250	0.002430	—	—	—	7.0000	0.003969	12	0.002862
0.5000	0.001191	2.3750	0.002001	18.0000	0.003931	—	48	—	0.1875	0.000650	—	—	—	0.6875	0.001244	2¾	—	—	2.7500	0.002487	—	—	—	7.5000	0.004108	11	0.003033
0.5625	0.001238	2.4375	0.002019	20.0000	0.004072	#10	—	—	0.1900	0.000654	—	—	28	0.7143	0.001268	—	—	—	2.8750	0.002543	—	—	—	8.0000	0.004243	10	0.003232
0.6250	0.001282	2.5000	0.002036	24.0000	0.004327	—	—	—	0.2031	0.000676	¾	12	—	0.7500	0.001299	3	—	—	3.0000	0.002598	—	—	—	8.5000	0.004373	9	0.003467
0.6875	0.001324	2.6250	0.002069	—	—	#12	—	—	0.2160	0.000697	—	—	—	0.8125	0.001352	—	—	—	3.1250	0.002652	—	—	—	9.0000	0.004500	8	0.003750
0.7500	0.001363	2.7500	0.002102	—	—	—	—	—	0.2188	0.000702	—	—	24	0.8333	0.001369	3¼	—	—	3.2500	0.002704	—	—	—	9.5000	0.004623	7	0.004099
0.8125	0.001400	2.8750	0.002133	—	—	—	40	—	0.2250	0.000712	7/8	—	—	0.8750	0.001403	—	—	6	3.3333	0.002739	—	—	—	10.0000	0.004743	6	0.004543
0.8750	0.001435	3.0000	0.002163	—	—	—	—	—	0.2344	0.000726	—	10	—	0.9000	0.001423	—	—	—	3.3750	0.002756	—	—	—	10.5000	0.004861	5	0.005130
0.9375	0.001468	3.1250	0.002193	—	—	¼	36	80	0.2500	0.000750	—	—	—	0.9375	0.001452	3½	—	—	3.5000	0.002806	—	—	—	11.0000	0.004975	4½	0.005503
1.0000	0.001500	3.2500	0.002222	—	—	—	—	—	0.2656	0.000773	1	—	20	1.0000	0.001500	—	—	—	3.6250	0.002856	—	—	—	11.5000	0.005087	4	0.005953
1.0625	0.001531	3.3750	0.002250	—	—	—	—	72	0.2778	0.000791	—	—	—	1.0625	0.001546	3¾	—	—	3.7500	0.002905	—	—	—	12.0000	0.005196	—	—
1.1250	0.001560	3.5000	0.002277	—	—	—	32	—	0.2813	0.000796	—	—	18	1.1111	0.001581	—	—	—	3.8750	0.002953	—	—	—	—	—	—	—
1.1875	0.001588	3.6250	0.002304	—	—	—	—	—	0.2969	0.000817	1⅛	8	—	1.1250	0.001591	4	—	—	4.0000	0.003000	—	—	—	—	—	—	—
1.2500	0.001616	3.7500	0.002330	—	—	5/16	—	64	0.3125	0.000839	—	—	—	1.1875	0.001635	—	—	—	4.1250	0.003047	—	—	—	—	—	—	—

[a] Class 2A tolerances are the bases for the tolerances of Classes 1A, 3A, 1B, 2B, and 3B.

[b] Pitch-diameter tolerance = $0.0015\sqrt[3]{D} + 0.0015\sqrt{L_e} + 0.015\sqrt[3]{p^2}$.

TABLE 34—*Class 2,*[a] *Increments in Pitch-Diameter Tolerance*[b]

DIAMETER						LENGTH OF ENGAGEMENT								PITCH	
D	$0.002\sqrt{D}$	D	$0.002\sqrt{D}$	D	$0.002\sqrt{D}$	L_e	$0.00133L_e$	L_e	$0.00133L_e$	L_e	$0.00133L_e$	L_e	$0.00133L_e$	Threads per inch	$0.010\sqrt{p}$
0.0600	0.000490	1.1875	0.002179	3.1250	0.003536	0.0600	0.000080	0.3281	0.000436	1.7500	0.002328	5.0000	0.006650	80	0.001118
0.0625	0.000500	1.2500	0.002236	3.2500	0.003606	0.0625	0.000083	0.3438	0.000457	1.8750	0.002494	5.1250	0.006816	72	0.001179
0.0730	0.000540	1.3125	0.002291	3.3750	0.003674	0.0730	0.000097	0.3594	0.000478	2.0000	0.002660	5.2500	0.006982	64	0.001250
0.0860	0.000587	1.3750	0.002345	3.5000	0.003742	0.0781	0.000104	0.3750	0.000499	2.1250	0.002826	5.3750	0.007149	56	0.001336
0.0990	0.000629	1.4375	0.002398	3.6250	0.003808	0.0860	0.000114	0.3906	0.000519	2.2500	0.002992	5.5000	0.007315	48	0.001443
0.1120	0.000669	1.5000	0.002449	3.7500	0.003873	0.0938	0.000125	0.4063	0.000540	2.3750	0.003159	5.6250	0.007481	44	0.001508
0.1250	0.000707	1.5625	0.002500	3.8750	0.003937	0.0990	0.000132	0.4219	0.000561	2.5000	0.003325	5.7500	0.007648	40	0.001581
0.1380	0.000743	1.6250	0.002550	4.0000	0.004000	0.1094	0.000146	0.4375	0.000582	2.6250	0.003491	5.8750	0.007814	36	0.001667
0.1640	0.000810	1.6875	0.002598	4.2500	0.004123	0.1120	0.000149	0.5000	0.000665	2.7500	0.003658	6.0000	0.007980	32	0.001768
0.1900	0.000872	1.7500	0.002646	4.5000	0.004243	0.1250	0.000166	0.5625	0.000748	2.8750	0.003824	6.5000	0.008645	28	0.001890
0.2160	0.000930	1.8125	0.002693	4.7500	0.004359	0.1380	0.000184	0.6250	0.000831	3.0000	0.003990	7.0000	0.009310	24	0.002041
0.2500	0.001000	1.8750	0.002739	5.0000	0.004472	0.1406	0.000187	0.6875	0.000914	3.1250	0.004156	7.5000	0.009975	20	0.002236
0.3125	0.001118	1.9375	0.002784	5.2500	0.004583	0.1563	0.000208	0.7500	0.000998	3.2500	0.004322	8.0000	0.010640	18	0.002357
0.3750	0.001225	2.0000	0.002828	5.5000	0.004690	0.1640	0.000218	0.8125	0.001081	3.3750	0.004489	8.5000	0.011305	16	0.002500
0.4375	0.001323	2.0625	0.002872	5.7500	0.004796	0.1719	0.000229	0.8750	0.001164	3.5000	0.004655	9.0000	0.011970	14	0.002673
0.5000	0.001414	2.1250	0.002915	6.0000	0.004899	0.1875	0.000249	0.9375	0.001247	3.6250	0.004821	9.5000	0.012635	13	0.002774
0.5625	0.001500	2.1875	0.002958	7.0000	0.005292	0.1900	0.000253	1.0000	0.001330	3.7500	0.004988	10.0000	0.013300	12	0.002887
0.6250	0.001581	2.2500	0.003000	8.0000	0.005657	0.2031	0.000270	1.0625	0.001413	3.8750	0.005154	10.5000	0.013965	11	0.003015
0.6875	0.001658	2.3125	0.003041	9.0000	0.006000	0.2160	0.000287	1.1250	0.001496	4.0000	0.005320	11.0000	0.014630	10	0.003162
0.7500	0.001732	2.3750	0.003082	10.0000	0.006325	0.2188	0.000291	1.1875	0.001579	4.1250	0.005486	11.5000	0.015295	9	0.003333
0.8125	0.001803	2.4375	0.003122	12.0000	0.006928	0.2344	0.000312	1.2500	0.001662	4.2500	0.005652	12.0000	0.015960	8	0.003536
0.8750	0.001871	2.5000	0.003162	14.0000	0.007483	0.2500	0.000332	1.3125	0.001746	4.3750	0.005819	—	—	7	0.003780
0.9375	0.001936	2.6250	0.003240	16.0000	0.008000	0.2656	0.000353	1.3750	0.001829	4.5000	0.005985	—	—	6	0.004082
1.0000	0.002000	2.7500	0.003317	18.0000	0.008485	0.2813	0.000374	1.4375	0.001912	4.6250	0.006151	—	—	5	0.004472
1.0625	0.002062	2.8750	0.003391	20.0000	0.008944	0.2969	0.000395	1.5000	0.001995	4.7500	0.006318	—	—	4½	0.004714
1.1250	0.002121	3.0000	0.003464	24.0000	0.009798	0.3125	0.000416	1.6250	0.002161	4.8750	0.006484	—	—	4	0.005000

[a] Class 3 tolerances are 70% of Class 2 tolerances.
[b] Pitch-diameter tolerance = $0.002\sqrt{D} + 0.00133L_e + 0.010\sqrt{p}$.

Appendix G

TABLE 35—*Class 1 (Only), Values for Obtaining Thread Dimensions of Special Screw Threads*

THREADS PER INCH	EXTERNAL THREAD SIZES[a]				INTERNAL THREAD SIZES[b]			
	Major diameter		Maximum pitch diameter	Maximum minor diameter[c]	Minor diameter		Minimum pitch diameter	Minimum major diameter[d]
	Maximum	Tolerance			Minimum	Tolerance		
64	0.0007	0.0052	0.0108	0.0199	0.0169	0.0017	0.0101	0.0000
56	0.0008	0.0056	0.0124	0.0227	0.0193	0.0019	0.0116	0.0000
48	0.0009	0.0062	0.0144	0.0265	0.0226	0.0023	0.0135	0.0000
40	0.0010	0.0068	0.0172	0.0317	0.0271	0.0027	0.0162	0.0000
36	0.0011	0.0072	0.0191	0.0352	0.0301	0.0030	0.0180	0.0000
32	0.0011	0.0076	0.0214	0.0394	0.0338	0.0034	0.0203	0.0000
28	0.0012	0.0086	0.0244	0.0450	0.0387	0.0039	0.0232	0.0000
24	0.0013	0.0092	0.0284	0.0524	0.0451	0.0045	0.0271	0.0000
20	0.0015	0.0102	0.0340	0.0628	0.0541	0.0054	0.0325	0.0000
18	0.0016	0.0114	0.0377	0.0698	0.0601	0.0060	0.0361	0.0000
16	0.0018	0.0126	0.0424	0.0785	0.0677	0.0068	0.0406	0.0000
14	0.0021	0.0140	0.0485	0.0897	0.0773	0.0077	0.0464	0.0000
12	0.0024	0.0158	0.0565	0.1046	0.0902	0.0090	0.0541	0.0000
10	0.0028	0.0184	0.0678	0.1255	0.1083	0.0108	0.0650	0.0000
8	0.0034	0.0222	0.0846	0.1568	0.1353	0.0135	0.0812	0.0000
6	0.0044	0.0290	0.1127	0.2089	0.1804	0.0180	0.1083	0.0000
4	0.0064	0.0408	0.1688	0.3131	0.2706	0.0270	0.1624	0.0000

[a] To obtain maximum dimensions for major, pitch, and minor diameters, subtract the values in the "Maximum" columns from the basic major diameter. Apply tolerances minus. See Table 36 for pitch-diameter tolerances.
[b] To obtain minimum dimensions for minor, pitch, and major diameters, subtract the values in the "Minimum" columns from the basic major diameter. Apply tolerances plus. See Table 36 for pitch-diameter tolerances.
[c] Dimensions given for the maximum minor diameter of the external thread are figured to the intersection of the worn tool arc with a center line through crest and root. The minimum minor diameter of the external thread shall be that corresponding to a flat at the minor diameter of the minimum external thread equal to $\frac{1}{8} \times p$, and may be determined by subtracting the basic thread depth, h_b (or $0.6495p$), from the minimum pitch diameter of the external thread.
[d] Dimensions for the minimum major diameter of the internal thread correspond to the basic flat ($\frac{1}{8} \times p$), and the profile at the major diameter produced by a worn tool must not fall below the basic outline. The maximum major diameter of the internal thread shall be that corresponding to a flat at the major diameter of the maximum internal thread equal to $\frac{1}{24} \times p$, and may be determined by adding $1\frac{1}{16} \times h_b$ (or $0.7939p$) to the maximum pitch diameter of the internal thread.

TABLE 36—*Class 1 (Only), Pitch-Diame*

THREADS PER INCH	LENGTHS OF ENGAGEMENT IN INCHES		PITCH-DIAMETER TOLERANCES FOR DIAMETERS UP TO AND INCLUDING—									
	From	To and including	1/16	1/8	3/16	1/4	3/8	1/2	3/4	1	1 1/2	2
64	—	1/2	0.0026	0.0026	0.0034	0.0038	0.0042	0.0044	0.0047	0.0050	0.0052	—
56	—	1/2	0.0028	0.0028	0.0034	0.0038	0.0044	0.0046	0.0049	0.0052	0.0056	—
	1/2	1 1/2	0.0052	0.0054	0.0055	0.0056	*0.0056*	*0.0056*	*0.0056*	*0.0056*	*0.0056*	—
48	—	1/2	0.0031	0.0031	0.0034	0.0038	0.0046	0.0048	0.0051	0.0054	0.0058	0.0062
	1/2	1 1/2	0.0054	0.0056	0.0057	0.0057	0.0057	0.0057	0.0057	0.0062	*0.0062*	*0.0062*
40	—	1/2	0.0034	0.0034[b]	0.0034	0.0038	0.0046	0.0051	0.0054	0.0057	0.0061	0.0065
	1/2	1 1/2	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0068	*0.0068*	*0.0068*
36	—	1/2	—	0.0036	0.0036	0.0038	0.0046	0.0051	0.0056	0.0058	0.0063	0.0067
	1/2	1 1/2	—	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0070	0.0072	*0.0072*
32	—	1/2	—	0.0038	0.0038	0.0038	0.0046	0.0051	0.0057	0.0060	0.0065	0.0069
	1/2	1 1/2	—	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0070	0.0076	*0.0076*
28	—	1/2	—	—	0.0043	0.0043[c]	0.0046	0.0051	0.0057	0.0063	0.0067	0.0071
	1/2	1 1/2	—	—	0.0057	0.0057	0.0057	0.0057	0.0057	0.0070	0.0079	0.0086
24	—	1/2	—	—	0.0046	0.0046	0.0046[c]	0.0051	0.0057	0.0066	0.0070	0.0074
	1/2	1 1/2	—	—	0.0057	0.0057	0.0057	0.0057	0.0057	0.0070	0.0079	0.0089
20	—	1/2	—	—	0.0051	0.0051[b]	0.0051	0.0051[c]	0.0057	0.0070	0.0074	0.0078
	1/2	1 1/2	—	—	0.0057	0.0057	0.0057	0.0057	0.0057	0.0070	0.0079	0.0093
	1 1/2	3	—	—	0.0098	0.0100	0.0102	*0.0102*	*0.0102*	*0.0102*	*0.0102*	*0.0102*
18	—	1/2	—	—	—	0.0057	0.0057	0.0057	0.0057	0.0070	0.0077	0.0080
	1/2	1 1/2	—	—	—	0.0057	0.0057	0.0057	0.0057	0.0070	0.0079	0.0095
	1 1/2	3	—	—	—	0.0102	0.0104	0.0106	0.0109	0.0112	0.0114	*0.0114*
16	—	1/2	—	—	—	0.0063	0.0063[b]	0.0063	0.0063	0.0070	0.0079	0.0083
	1/2	1 1/2	—	—	—	0.0063	0.0063	0.0063	0.0063[c]	0.0070	0.0079	0.0098
	1 1/2	3	—	—	—	0.0105	0.0107	0.0109	0.0112	0.0115	0.0120	0.0123
14	—	1/2	—	—	—	—	0.0070	0.0070	0.0070	0.0070	0.0079	0.0087
	1/2	1 1/2	—	—	—	—	0.0070	0.0070	0.0070	0.0070[c]	0.0079	0.0102
	1 1/2	3	—	—	—	—	0.0111	0.0113	0.0116	0.0119	0.0123	0.0127
12	—	1/2	—	—	—	—	0.0075	0.0077	0.0079	0.0079	0.0079	0.0091
	1/2	1 1/2	—	—	—	—	0.0079	0.0079	0.0079	0.0079	0.0079[c]	0.0106
	1 1/2	3	—	—	—	—	0.0115	0.0117	0.0120	0.0123	0.0127	0.0131
10	—	1	—	—	—	—	—	0.0087	0.0092[b]	0.0098	0.0102	0.0106
	1	3	—	—	—	—	—	0.0117	0.0120	0.0123	0.0128	0.0132
	3	6	—	—	—	—	—	0.0167	0.0171	0.0173	0.0178	0.0181
8	—	1	—	—	—	—	—	0.0095	0.0098	0.0111[b]	0.0111	0.0111
	1	3	—	—	—	—	—	0.0125	0.0128	0.0131	0.0135	0.0139
	3	6	—	—	—	—	—	0.0175	0.0178	0.0181	0.0185	0.0189
6	—	1	—	—	—	—	—	—	0.0109	0.0112	0.0116	0.0120
	1	3	—	—	—	—	—	—	0.0139	0.0142	0.0145[b]	0.0150
	3	6	—	—	—	—	—	—	0.0189	0.0192	0.0196	0.0200
4	—	1	—	—	—	—	—	—	—	0.0130	0.0134	0.0138
	1	3	—	—	—	—	—	—	—	0.0160	0.0164	0.0168
	3	6	—	—	—	—	—	—	—	0.0210	0.0215	0.0218

[a] It is preferable to avoid the use of tolerances set in italics by choosing a closer fit, shorter length of engagement, coarser pitch, or smaller diameter. When the length of engagement exceeds one diameter and the pitch-diameter tolerance exceeds 90% of the major-diameter tolerance, Table 35, column 3, the major-diameter tolerance shall be 110% of the pitch-diameter tolerance.

[b] Standard size of the coarse-thread series.

[c] Standard size of the fine-thread series.

ter Tolerances[a] for Special Screw Threads

PITCH-DIAMETER TOLERANCES FOR DIAMETER UP TO AND INCLUDING—											THREADS PER INCH
3	4	6	8	10	12	14	16	18	20	24	
—	—	—	—	—	—	—	—	—	—	—	64
—	—	—	—	—	—	—	—	—	—	—	56
—	—	—	—	—	—	—	—	—	—	—	48
—	—	—	—	—	—	—	—	—	—	—	40
0.0072	—	—	—	—	—	—	—	—	—	—	36
0.0072	—	—	—	—	—	—	—	—	—	—	
0.0075	—	—	—	—	—	—	—	—	—	—	32
0.0076	—	—	—	—	—	—	—	—	—	—	
0.0077	0.0083	—	—	—	—	—	—	—	—	—	28
0.0086	*0.0086*	—	—	—	—	—	—	—	—	—	
0.0080	0.0086	—	—	—	—	—	—	—	—	—	24
0.0092	*0.0092*	—	—	—	—	—	—	—	—	—	
0.0084	0.0090	0.0099	—	—	—	—	—	—	—	—	20
0.0099	0.0102	*0.0102*	—	—	—	—	—	—	—	—	
0.0102	*0.0102*	*0.0102*	—	—	—	—	—	—	—	—	
0.0087	0.0092	0.0101	0.0109	0.0114	—	—	—	—	—	—	18
0.0102	0.0107	0.0114	*0.0114*	*0.0114*	—	—	—	—	—	—	
0.0114	*0.0114*	*0.0114*	*0.0114*	*0.0114*	—	—	—	—	—	—	
0.0090	0.0095	0.0104	0.0112	0.0118	0.0124	—	—	—	—	—	16
0.0105	0.0110	0.0119	0.0126	*0.0126*	*0.0126*	—	—	—	—	—	
0.0126	*0.0126*	*0.0126*	*0.0126*	*0.0126*	*0.0126*	—	—	—	—	—	
0.0093	0.0099	0.0108	0.0115	0.0122	0.0128	0.0133	0.0138	—	—	—	14
0.0108	0.0114	0.0123	0.0130	0.0137	0.0140	*0.0140*	*0.0140*	—	—	—	
0.0133	0.0139	0.0140	*0.0140*	*0.0140*	*0.0140*	*0.0140*	*0.0140*	—	—	—	
0.0097	0.0103	0.0112	0.0119	0.0126	0.0132	0.0138	0.0143	0.0148	0.0152	—	12
0.0112	0.0118	0.0127	0.0134	0.0141	0.0147	0.0153	0.0158	*0.0158*	*0.0158*	—	
0.0137	0.0143	0.0152	0.0158	*0.0158*	*0.0158*	*0.0158*	*0.0158*	*0.0158*	*0.0158*	—	
0.0112	0.0118	0.0127	0.0134	0.0141	0.0147	0.0153	0.0158	0.0158	0.0163	0.0171	10
0.0138	0.0143	0.0152	0.0160	0.0166	0.0172	0.0178	0.0183	*0.0184*	*0.0184*	*0.0184*	
0.0184	*0.0184*	*0.0184*	*0.0184*	*0.0184*	*0.0184*	*0.0184*	*0.0184*	*0.0184*	*0.0184*	*0.0184*	
0.0115	0.0121	0.0130	0.0137	0.0144	0.0150	0.0156	0.0161	0.0166	0.0170	0.0179	8
0.0145	0.0151	0.0160	0.0167	0.0174	0.0180	0.0186	0.0191	0.0196	0.0200	0.0209	
0.0195	0.0201	0.0210	0.0217	0.0222	*0.0222*	*0.0222*	*0.0222*	*0.0222*	*0.0222*	*0.0222*	
0.0126	0.0132	0.0141	0.0148	0.0155	0.0161	0.0166	0.0172	0.0176	0.0181	0.0190	6
0.0156	0.0162	0.0171	0.0178	0.0185	0.0191	0.0196	0.0202	0.0206	0.0211	0.0220	
0.0206	0.0212	0.0221	0.0228	0.0235	0.0241	0.0246	0.0252	0.0256	0.0261	0.0270	
0.0145	0.0150	0.0159	0.0167	0.0173	0.0179	0.0185	0.0190	0.0195	0.0199	0.0208	4
0.0204[b]	0.0204	0.0204	0.0204	0.0204	0.0209	0.0215	0.0220	0.0225	0.0229	0.0238	
0.0225	0.0230	0.0239	0.0247	0.0253	0.0259	0.0265	0.0270	0.0275	0.0279	0.0288	

Appendix H

TABLE 37a—*Classes 1B, 2B, and 3B*,[a] *Recommended Hole-Size Limits Before Threading for Different Lengths of Engagement—UNC, UNF, UNEF, UN, NC, NF, NEF, and N Series*

DESIGNATION		MINOR-DIAMETER INTERNAL THREADS				RECOMMENDED HOLE-SIZE LIMITS FOR DIFFERENT LENGTHS OF ENGAGEMENT							
Thread size	Threads per inch	Minimum	Per cent basic thread height	Maximum[b]	Per cent basic thread height	To and including ½ *D*		Above ½ *D* to ⅔ *D*		Above ⅔ *D* to 1½ *D*		Above 1½ *D* to 3 *D*	
						Min	Max	Min	Max	Min	Max	Min	Max
0 (0.060)	80	0.0465	83.1	0.0514	52.9	0.0465	0.0500	0.0479	0.0514	0.0479	0.0514	0.0479	0.0514
1 (0.073)	64	0.0561	83.3	0.0623	52.7	0.0561	0.0599	0.0585	0.0623	0.0585	0.0623	0.0585	0.0623
1 (0.073)	72	0.0580	83.1	0.0635	52.7	0.0580	0.0613	0.0596	0.0629	0.0602	0.0635	0.0602	0.0635
2 (0.086)	56	0.0667	83.2	0.0737	53.0	0.0667	0.0705	0.0686	0.0724	0.0699	0.0737	0.0699	0.0737
2 (0.086)	64	0.0691	83.3	0.0753	52.7	0.0691	0.0724	0.0707	0.0740	0.0720	0.0753	0.0720	0.0753
3 (0.099)	48	0.0764	83.5	0.0845	53.6	0.0764	0.0804	0.0785	0.0825	0.0805	0.0845	0.0806	0.0846
3 (0.099)	56	0.0797	83.2	0.0865	53.9	0.0797	0.0831	0.0814	0.0848	0.0831	0.0865	0.0833	0.0867
4 (0.112)	40	0.0849	83.4	0.0939	55.7	0.0849	0.0894	0.0871	0.0916	0.0894	0.0939	0.0902	0.0947
4 (0.112)	48	0.0894	83.5	0.0968	56.2	0.0894	0.0931	0.0912	0.0949	0.0931	0.0968	0.0939	0.0976
5 (0.125)	40	0.0979	83.4	0.1062	57.9	0.0979	0.1020	0.1000	0.1041	0.1021	0.1062	0.1036	0.1077
5 (0.125)	44	0.1004	83.3	0.1079	57.9	0.1004	0.1041	0.1023	0.1060	0.1042	0.1079	0.1060	0.1097
6 (0.138)	32	0.1042	83.3	0.1140	59.1	0.1042	0.1091	0.1066	0.1115	0.1091	0.1140	0.1115	0.1164
6 (0.138)	40	0.1109	83.4	0.1186	59.7	0.1109	0.1148	0.1128	0.1167	0.1147	0.1186	0.1166	0.1205
8 (0.164)	32	0.1302	83.3	0.1389	61.8	0.1302	0.1345	0.1324	0.1367	0.1346	0.1389	0.1367	0.1410
8 (0.164)	36	0.1339	83.4	0.1416	62.1	0.1339	0.1397	0.1339	0.1397	0.1358	0.1416	0.1377	0.1435
10 (0.190)	24	0.1449	83.3	0.1555	63.7	0.1449	0.1502	0.1475	0.1528	0.1502	0.1555	0.1528	0.1581
10 (0.190)	32	0.1562	83.3	0.1641	63.8	0.1562	0.1601	0.1581	0.1621	0.1601	0.1641	0.1621	0.1661
12 (0.216)	24	0.1709	83.3	0.1807	65.2	0.1709	0.1758	0.1733	0.1782	0.1758	0.1807	0.1782	0.1831
12 (0.216)	28	0.1773	83.4	0.1857	65.3	0.1773	0.1815	0.1794	0.1836	0.1815	0.1857	0.1836	0.1878
12 (0.216)	32	0.1822	83.3	0.1895	65.3	0.1822	0.1858	0.1837	0.1877	0.1855	0.1895	0.1873	0.1913
¼	20	0.1959	83.3	0.2067	66.7	0.1959	0.2013	0.1986	0.2040	0.2013	0.2067	0.2040	0.2094
¼	28	0.2113	83.4	0.2190	66.8	0.2113	0.2152	0.2131	0.2171	0.2150	0.2190	0.2169	0.2209
¼	32	0.2162	83.3	0.2229	66.8	0.2162	0.2196	0.2172	0.2212	0.2189	0.2229	0.2206	0.2246
¼	36	0.2199	83.4	0.2258	67.1	0.2199	0.2243	0.2199	0.2243	0.2214	0.2258	0.2229	0.2273
5/16	18	0.2524	83.3	0.2630	68.6	0.2524	0.2577	0.2551	0.2604	0.2577	0.2630	0.2604	0.2657
5/16	24	0 2674	83.3	0.2754	68.5	0.2674	0.2714	0.2694	0.2734	0.2714	0.2754	0.2734	0.2774
5/16	32	0.2787	83.3	0.2847	68.5	0.2787	0.2817	0.2792	0.2832	0.2807	0.2847	0.2822	0.2862
5/16	36	0.2824	83.4	0.2877	68.7	0.2824	0.2863	0.2824	0.2863	0.2837	0.2877	0.2850	0.2890
⅜	16	0.3073	83.4	0.3182	70.0	0.3073	0.3127	0.3101	0.3155	0.3128	0.3182	0.3155	0.3209
⅜	24	0.3299	83.3	0.3372	69.8	0.3299	0.3336	0.3314	0.3354	0.3332	0.3372	0.3351	0.3391
⅜	32	0.3412	83.3	0.3469	69.2	0.3412	0.3441	0.3415	0.3455	0.3429	0.3469	0.3444	0.3484
⅜	36	0.3449	83.4	0.3501	69.0	0.3449	0.3488	0.3449	0.3488	0.3461	0.3501	0.3474	0.3514

[a] Based on Table 31. The differences between limits are equal to the minor-diameter tolerances given in Table 31 for lengths of engagement to and including ½*D*. However, the minimum values for lengths of engagement greater than ½*D* and for sizes ¼ in. and larger are adjusted so that the difference between limits is never less than 0.0040 in. For diameter-pitch combinations other than those given in this table, the tolerances given in Table 31 should be similarly applied to determine hole-size limits.

[b] Based on length of engagement equal to the nominal diameter.

TABLE 37b—*Classes 1B, 2B, and 3B*,[a] *Recommended Hole-Size Limits Before Threading for Different Lengths of Engagement—UNC, UNF, UNEF, UN, NC, NF, NEF, and N Series*

DESIGNATION		MINOR-DIAMETER INTERNAL THREADS				RECOMMENDED HOLE-SIZE LIMITS FOR DIFFERENT LENGTHS OF ENGAGEMENT							
Thread size	Threads per inch	Minimum	Per cent basic thread height	Maximum[b]	Per cent basic thread height	To and including ½ *D*		Above ½ *D* to ⅔ *D*		Above ⅔ *D* to 1½ *D*		Above 1½ *D* to 3 *D*	
						Min	Max	Min	Max	Min	Max	Min	Max
7/16	14	0.3602	83.3	0.3717	70.9	0.3602	0.3660	0.3630	0.3688	0.3659	0.3717	0.3688	0.3746
7/16	20	0.3834	83.3	0.3916	70.7	0.3834	0.3875	0.3855	0.3896	0.3875	0.3916	0.3896	0.3937
7/16	28	0.3988	83.4	0.4051	70.0	0.3988	0.4020	0.3995	0.4035	0.4011	0.4051	0.4017	0.4067
1/2	13	0.4167	83.4	0.4284	71.7	0.4167	0.4225	0.4196	0.4254	0.4226	0.4284	0.4255	0.4313
1/2	12	0.4098	83.3	0.4223	71.8	0.4098	0.4161	0.4129	0.4192	0.4160	0.4223	0.4192	0.4255
1/2	20	0.4459	83.3	0.4537	71.3	0.4459	0.4498	0.4477	0.4517	0.4497	0.4537	0.4516	0.4556
1/2	28	0.4613	83.4	0.4676	70.0	0.4613	0.4645	0.4620	0.4660	0.4636	0.4676	0.4652	0.4692
9/16	12	0.4723	83.3	0.4843	72.2	0.4723	0.4783	0.4753	0.4813	0.4783	0.4843	0.4813	0.4873
9/16	18	0.5024	83.3	0.5106	71.9	0.5024	0.5065	0.5045	0.5086	0.5065	0.5106	0.5086	0.5127
9/16	24	0.5174	83.3	0.5244	70.4	0.5174	0.5209	0.5186	0.5226	0.5204	0.5244	0.5221	0.5261
9/16	28	0.5238	83.4	0.5301	69.8	0.5238	0.5270	0.5245	0.5285	0.5261	0.5301	0.5277	0.5317
5/8	11	0.5266	83.3	0.5391	72.7	0.5266	0.5328	0.5298	0.5360	0.5329	0.5391	0.5360	0.5422
5/8	12	0.5348	83.3	0.5463	72.7	0.5348	0.5406	0.5377	0.5435	0.5405	0.5463	0.5434	0.5492
5/8	18	0.5649	83.3	0.5730	72.1	0.5649	0.5690	0.5670	0.5711	0.5690	0.5730	0.5711	0.5752
5/8	24	0.5799	83.3	0.5869	70.4	0.5799	0.5834	0.5811	0.5851	0.5829	0.5869	0.5846	0.5886
5/8	28	0.5863	83.4	0.5926	69.8	0.5863	0.5895	0.5870	0.5910	0.5886	0.5926	0.5902	0.5942
11/16	12	0.5973	83.3	0.6085	73.0	0.5973	0.6029	0.6001	0.6057	0.6029	0.6085	0.6057	0.6113
11/16	24	0.6424	83.3	0.6494	70.4	0.6424	0.6459	0.6436	0.6476	0.6454	0.6494	0.6471	0.6511
3/4	10	0.6417	83.4	0.6545	73.5	0.6417	0.6481	0.6449	0.6513	0.6481	0.6545	0.6513	0.6577
3/4	12	0.6598	83.3	0.6707	73.3	0.6598	0.6652	0.6626	0.6680	0.6653	0.6707	0.6680	0.6734
3/4	16	0.6823	83.4	0.6908	72.9	0.6823	0.6866	0.6844	0.6887	0.6865	0.6908	0.6886	0.6929
3/4	20	0.6959	83.3	0.7037	71.3	0.6959	0.6998	0.6977	0.7017	0.6997	0.7037	0.7016	0.7056
3/4	28	0.7113	83.4	0.7176	69.8	0.7113	0.7145	0.7120	0.7160	0.7136	0.7176	0.7152	0.7192
13/16	12	0.7223	83.3	0.7329	73.5	0.7223	0.7276	0.7250	0.7303	0.7276	0.7329	0.7303	0.7356
13/16	16	0.7448	83.4	0.7533	72.9	0.7448	0.7491	0.7469	0.7512	0.7490	0.7533	0.7511	0.7554
13/16	20	0.7584	83.3	0.7662	71.3	0.7584	0.7623	0.7602	0.7642	0.7622	0.7662	0.7641	0.7681
7/8	9	0.7547	83.3	0.7681	74.1	0.7547	0.7614	0.7580	0.7647	0.7614	0.7681	0.7647	0.7714
7/8	12	0.7848	83.3	0.7952	73.7	0.7848	0.7900	0.7874	0.7926	0.7900	0.7952	0.7926	0.7978
7/8	14	0.7977	83.3	0.8068	73.5	0.7977	0.8022	0.8000	0.8045	0.8023	0.8068	0.8045	0.8090
7/8	16	0.8073	83.4	0.8158	72.9	0.8073	0.8116	0.8094	0.8137	0.8115	0.8158	0.8136	0.8179
7/8	20	0.8209	83.3	0.8287	71.3	0.8209	0.8248	0.8227	0.8267	0.8247	0.8287	0.8266	0.8306
7/8	28	0.8363	83.4	0.8426	69.8	0.8363	0.8395	0.8370	0.8410	0.8386	0.8426	0.8402	0.8442

[a] Based on Table 31. The differences between limits are equal to the minor-diameter tolerances given in Table 31 for lengths of engagement to and including ½*D*. However, the minimum values for lengths of engagement greater than ½*D* and for sizes ¼ in. and larger are adjusted so that the difference between limits is never less than 0.0040 in. For diameter-pitch combinations other than those given in this table, the tolerances given in Table 31 should be similarly applied to determine hole-size limits.

[b] Based on length of engagement equal to the nominal diameter.

TABLE 37c—*Classes 1B, 2B, and 3B*,[a] *Recommended Hole-Size Limits Before Threading for Different Lengths of Engagement—UNC, UNF, UNEF, UN, NC, NF, NEF, and N Series*

DESIGNATION		MINOR-DIAMETER INTERNAL THREADS				RECOMMENDED HOLE-SIZE LIMITS FOR DIFFERENT LENGTHS OF ENGAGEMENT							
						To and including ⅓ *D*		Above ⅓ *D* to ⅔ *D*		Above ⅔ *D* to 1½ *D*		Above 1½ *D* to 3 *D*	
Thread size	Threads per inch	Minimum	Per cent basic thread height	Maximum[b]	Per cent basic thread height	Min	Max	Min	Max	Min	Max	Min	Max
15/16	12	0.8473	83.3	0.8575	73.9	0.8473	0.8524	0.8499	0.8550	0.8524	0.8575	0.8550	0.8601
15/16	16	0.8698	83.4	0.8783	72.9	0.8698	0.8741	0.8719	0.8762	0.8740	0.8783	0.8761	0.8804
15/16	20	0.8834	83.3	0.8912	71.3	0.8834	0.8873	0.8852	0.8892	0.8872	0.8912	0.8891	0.8931
1	8	0.8647	83.3	0.8797	74.1	0.8647	0.8722	0.8684	0.8759	0.8722	0.8797	0.8760	0.8835
1	12	0.9098	83.3	0.9198	74.1	0.9098	0.9148	0.9123	0.9173	0.9148	0.9198	0.9173	0.9223
1	14	0.9227	83.3	0.9315	73.8	0.9227	0.9271	0.9249	0.9293	0.9271	0.9315	0.9293	0.9337
1	16	0.9323	83.4	0.9408	72.9	0.9323	0.9366	0.9344	0.9387	0.9365	0.9408	0.9386	0.9429
1	20	0.9459	83.3	0.9537	71.3	0.9459	0.9498	0.9477	0.9517	0.9497	0.9537	0.9516	0.9556
1	28	0.9613	83.4	0.9676	69.8	0.9613	0.9645	0.9620	0.9660	0.9636	0.9676	0.9652	0.9692
1 1/16	12	0.9723	83.3	0.9823	74.1	0.9723	0.9773	0.9748	0.9798	0.9773	0.9823	0.9798	0.9848
1 1/16	16	0.9948	83.4	1.0033	72.9	0.9948	0.9991	0.9969	1.0012	0.9990	1.0033	1.0011	1.0054
1 1/16	18	1.0024	83.3	1.0105	72.1	1.0024	1.0065	1.0044	1.0085	1.0064	1.0105	1.0085	1.0126
1 1/8	7	0.9704	83.3	0.9875	74.1	0.9704	0.9790	0.9747	0.9833	0.9789	0.9875	0.9832	0.9918
1 1/8	8	0.9897	83.3	1.0047	74.1	0.9897	0.9972	0.9934	1.0009	0.9972	1.0047	1.0010	1.0085
1 1/8	12	1.0348	83.3	1.0448	74.1	1.0348	1.0398	1.0373	1.0423	1.0398	1.0448	1.0423	1.0473
1 1/8	16	1.0573	83.4	1.0658	72.9	1.0573	1.0616	1.0594	1.0637	1.0615	1.0658	1.0636	1.0679
1 1/8	18	1.0649	83.3	1.0730	72.1	1.0649	1.0690	1.0669	1.0710	1.0689	1.0730	1.0710	1.0751
1 1/8	20	1.0709	83.3	1.0787	71.3	1.0709	1.0748	1.0727	1.0767	1.0747	1.0787	1.0766	1.0806
1 1/8	28	1.0863	83.4	1.0926	69.8	1.0863	1.0895	1.0870	1.0910	1.0886	1.0926	1.0902	1.0942
1 3/16	12	1.0973	83.3	1.1073	74.1	1.0973	1.1023	1.0998	1.1048	1.1023	1.1073	1.1048	1.1098
1 3/16	16	1.1198	83.4	1.1283	72.9	1.1198	1.1241	1.1219	1.1262	1.1240	1.1283	1.1261	1.1304
1 3/16	18	1.1274	83.3	1.1355	72.1	1.1274	1.1315	1.1294	1.1335	1.1314	1.1355	1.1335	1.1376
1 1/4	7	1.0954	83.3	1.1125	74.1	1.0954	1.1040	1.0997	1.1083	1.1039	1.1125	1.1082	1.1168
1 1/4	8	1.1147	83.3	1.1297	74.1	1.1147	1.1222	1.1184	1.1259	1.1222	1.1297	1.1260	1.1335
1 1/4	12	1.1598	83.3	1.1698	74.1	1.1598	1.1648	1.1623	1.1673	1.1648	1.1698	1.1673	1.1723
1 1/4	16	1.1823	83.4	1.1908	72.9	1.1823	1.1866	1.1844	1.1887	1.1865	1.1908	1.1886	1.1929
1 1/4	18	1.1899	83.3	1.1980	72.1	1.1899	1.1940	1.1919	1.1960	1.1939	1.1980	1.1960	1.2001
1 1/4	20	1.1959	83.3	1.2037	71.3	1.1959	1.1998	1.1977	1.2017	1.1997	1.2037	1.2016	1.2056
1 5/16	12	1.2223	83.3	1.2323	74.1	1.2223	1.2273	1.2248	1.2298	1.2273	1.2323	1.2298	1.2348
1 5/16	16	1.2448	83.4	1.2533	72.9	1.2448	1.2491	1.2469	1.2512	1.2490	1.2533	1.2511	1.2554
1 5/16	18	1.2524	83.3	1.2605	72.1	1.2524	1.2565	1.2544	1.2585	1.2564	1.2605	1.2585	1.2626

[a] Based on Table 31. The differences between limits are equal to the minor-diameter tolerances given in Table 31 for lengths of engagement to and including ⅓ *D*. However the minimum values for lengths of engagement greater than ⅓*D* and for sizes ¼ in. and larger are adjusted so that the difference between limits is never less than 0.0040 in. For diameter-pitch combinations other than those given in this table, the tolerances given in Table 31 should be similarly applied to determine hole-size limits.

[b] Based on length of engagement equal to the nominal diameter.

TABLE 37d—*Classes 1B, 2B, and 3B*,[a] *Recommended Hole-Size Limits Before Threading for Different Lengths of Engagement—UNC, UNF, UNEF, UN, NC, NF, NEF, and N Series*

DESIGNATION		MINOR-DIAMETER INTERNAL THREADS				RECOMMENDED HOLE-SIZE LIMITS FOR DIFFERENT LENGTHS OF ENGAGEMENT							
Thread size	Threads per inch	Minimum	Per cent basic thread height	Maximum[b]	Per cent basic thread height	To and including ⅛ *D*		Above ⅛ *D* to ⅜ *D*		Above ⅜ *D* to 1½ *D*		Above 1½ *D* to 3 *D*	
						Min	Max	Min	Max	Min	Max	Min	Max
1⅜	6	1.1946	83.3	1.2146	74.1	1.1946	1.2046	1.1996	1.2096	1.2046	1.2146	1.2096	1.2196
1⅜	8	1.2397	83.3	1.2547	74.1	1.2397	1.2472	1.2434	1.2509	1.2472	1.2547	1.2510	1.2585
1⅜	12	1.2848	83.3	1.2948	74.1	1.2848	1.2898	1.2873	1.2923	1.2898	1.2948	1.2923	1.2973
1⅜	16	1.3073	83.4	1.3158	72.9	1.3073	1.3116	1.3094	1.3137	1.3115	1.3158	1.3136	1.3179
1⅜	18	1.3149	83.3	1.3230	72.1	1.3149	1.3190	1.3169	1.3210	1.3189	1.3230	1.3210	1.3251
1⁷⁄₁₆	12	1.3473	83.3	1.3573	74.1	1.3473	1.3523	1.3498	1.3548	1.3523	1.3573	1.3548	1.3598
1⁷⁄₁₆	16	1.3698	83.4	1.3783	72.9	1.3698	1.3741	1.3719	1.3762	1.3740	1.3783	1.3761	1.3804
1⁷⁄₁₆	18	1.3774	83.3	1.3855	72.1	1.3774	1.3815	1.3794	1.3835	1.3814	1.3855	1.3835	1.3876
1½	6	1.3196	83.3	1.3396	74.1	1.3196	1.3296	1.3246	1.3346	1.3296	1.3396	1.3346	1.3446
1½	8	1.3647	83.3	1.3797	74.1	1.3647	1.3722	1.3684	1.3759	1.3722	1.3797	1.3760	1.3835
1½	12	1.4098	83.3	1.4198	74.1	1.4098	1.4148	1.4123	1.4173	1.4148	1.4198	1.4173	1.4223
1½	16	1.4323	83.4	1.4408	72.9	1.4323	1.4366	1.4344	1.4387	1.4365	1.4408	1.4386	1.4429
1½	18	1.4399	83.3	1.4480	72.1	1.4399	1.4440	1.4419	1.4460	1.4439	1.4480	1.4460	1.4501
1½	20	1.4459	83.3	1.4537	71.3	1.4459	1.4498	1.4477	1.4517	1.4497	1.4537	1.4516	1.4556
1⁹⁄₁₆	16	1.4948	83.4	1.5033	72.9	1.4948	1.4991	1.4969	1.5012	1.4990	1.5033	1.5011	1.5054
1⁹⁄₁₆	18	1.5024	83.3	1.5105	72.1	1.5024	1.5065	1.5044	1.5085	1.5064	1.5105	1.5085	1.5126
1⅝	8	1.4897	83.3	1.5047	74.1	1.4897	1.4972	1.4934	1.5009	1.4972	1.5047	1.5010	1.5085
1⅝	12	1.5348	83.3	1.5448	74.1	1.5348	1.5398	1.5373	1.5423	1.5398	1.5448	1.5423	1.5473
1⅝	16	1.5573	83.4	1.5658	72.9	1.5573	1.5616	1.5594	1.5637	1.5615	1.5658	1.5636	1.5679
1⅝	18	1.5649	83.3	1.5730	72.1	1.5649	1.5690	1.5669	1.5710	1.5689	1.5730	1.5710	1.5751
1¹¹⁄₁₆	16	1.6198	83.4	1.6283	72.9	1.6198	1.6241	1.6219	1.6262	1.6240	1.6283	1.6261	1.6304
1¹¹⁄₁₆	18	1.6274	83.3	1.6355	72.1	1.6274	1.6315	1.6294	1.6335	1.6314	1.6355	1.6335	1.6376
1¾	5	1.5335	83.3	1.5575	74.1	1.5335	1.5455	1.5395	1.5515	1.5455	1.5575	1.5515	1.5635
1¾	8	1.6147	83.3	1.6297	74.1	1.6147	1.6222	1.6184	1.6259	1.6222	1.6297	1.6260	1.6335
1¾	12	1.6598	83.3	1.6698	74.1	1.6598	1.6648	1.6623	1.6673	1.6648	1.6698	1.6673	1.6723
1¾	16	1.6823	83.4	1.6908	72.9	1.6823	1.6866	1.6844	1.6887	1.6865	1.6908	1.6886	1.6929
1¾	20	1.6959	83.3	1.7037	71.3	1.6959	1.6998	1.6977	1.7017	1.6997	1.7037	1.7016	1.7056
1¹³⁄₁₆	16	1.7448	83.4	1.7533	72.9	1.7448	1.7491	1.7469	1.7512	1.7490	1.7533	1.7511	1.7554
1⅞	8	1.7397	83.3	1.7547	74.1	1.7397	1.7472	1.7434	1.7509	1.7472	1.7547	1.7510	1.7585
1⅞	12	1.7848	83.3	1.7948	74.1	1.7848	1.7898	1.7873	1.7923	1.7898	1.7948	1.7923	1.7973
1⅞	16	1.8073	83.4	1.8158	72.9	1.8073	1.8116	1.8094	1.8137	1.8115	1.8158	1.8136	1.8179

[a] Based on Table 31. The differences between limits are equal to the minor-diameter tolerances given in Table 31 for lengths of engagement to and including ⅛ *D*. However the minimum values for lengths of engagement greater than ⅛ *D* and for sizes ¼ in. and larger are adjusted so that the difference between limits is never less than 0.0040 in. For diameter-pitch combinations other than those given in this table, the tolerances given in Table 31 should be similarly applied to determine hole-size limits.

[b] Based on length of engagement equal to the nominal diameter.

TABLE 37e—*Classes 1B, 2B, and 3B*,[a] *Recommended Hole-Size Limits Before Threading for Different Lengths of Engagement—UNC, UNF, UNEF, UN, NC, NF, NEF, and N Series*

DESIGNATION		MINOR-DIAMETER INTERNAL THREADS				RECOMMENDED HOLE-SIZE LIMITS FOR DIFFERENT LENGTHS OF ENGAGEMENT							
						To and including $\frac{1}{3}D$		Above $\frac{1}{3}D$ to $\frac{2}{3}D$		Above $\frac{2}{3}D$ to $1\frac{1}{2}D$		Above $1\frac{1}{2}D$ to $3D$	
Thread size	Threads per inch	Minimum	Per cent basic thread height	Maximum[b]	Per cent basic thread height	Min	Max	Min	Max	Min	Max	Min	Max
$1\frac{5}{16}$	16	1.8698	83.4	1.8783	72.9	1.8698	1.8741	1.8719	1.8762	1.8740	1.8783	1.8761	1.8804
2	$4\frac{1}{2}$	1.7594	83.3	1.7861	74.1	1.7594	1.7727	1.7661	1.7794	1.7728	1.7861	1.7794	1.7927
2	8	1.8647	83.3	1.8797	74.1	1.8647	1.8722	1.8684	1.8759	1.8722	1.8797	1.8760	1.8835
2	12	1.9098	83.3	1.9198	74.1	1.9098	1.9148	1.9123	1.9173	1.9148	1.9198	1.9173	1.9223
2	16	1.9323	83.4	1.9408	72.9	1.9323	1.9366	1.9344	1.9387	1.9365	1.9408	1.9386	1.9429
2	20	1.9459	83.3	1.9537	71.3	1.9459	1.9498	1.9477	1.9517	1.9497	1.9537	1.9516	1.9556
$2\frac{1}{16}$	16	1.9948	83.4	2.0033	72.9	1.9948	1.9991	1.9969	2.0012	1.9990	2.0033	2.0011	2.0054
$2\frac{1}{8}$	8	1.9897	83.3	2.0047	74.1	1.9897	1.9972	1.9934	2.0009	1.9972	2.0047	2.0010	2.0085
$2\frac{1}{8}$	12	2.0348	83.3	2.0448	74.1	2.0348	2.0398	2.0373	2.0423	2.0398	2.0448	2.0423	2.0473
$2\frac{1}{8}$	16	2.0573	83.4	2.0658	72.9	2.0573	2.0616	2.0594	2.0637	2.0615	2.0658	2.0636	2.0679
$2\frac{3}{16}$	16	2.1198	83.4	2.1283	72.9	2.1198	2.1241	2.1219	2.1262	2.1240	2.1283	2.1261	2.1304
$2\frac{1}{4}$	$4\frac{1}{2}$	2.0094	83.3	2.0361	74.1	2.0094	2.0227	2.0161	2.0294	2.0228	2.0361	2.0294	2.0427
$2\frac{1}{4}$	8	2.1147	83.3	2.1297	74.1	2.1147	2.1222	2.1184	2.1259	2.1222	2.1297	2.1260	2.1335
$2\frac{1}{4}$	12	2.1598	83.3	2.1698	74.1	2.1598	2.1648	2.1623	2.1673	2.1648	2.1698	2.1673	2.1723
$2\frac{1}{4}$	16	2.1823	83.4	2.1908	72.9	2.1823	2.1866	2.1844	2.1887	2.1865	2.1908	2.1886	2.1929
$2\frac{1}{4}$	20	2.1959	83.3	2.2037	71.3	2.1959	2.1998	2.1977	2.2017	2.1997	2.2037	2.2016	2.2056
$2\frac{5}{16}$	16	2.2448	83.4	2.2533	72.9	2.2448	2.2491	2.2469	2.2512	2.2490	2.2533	2.2511	2.2554
$2\frac{3}{8}$	12	2.2848	83.3	2.2948	74.1	2.2848	2.2898	2.2873	2.2923	2.2898	2.2948	2.2923	2.2973
$2\frac{3}{8}$	16	2.3073	83.4	2.3158	72.9	2.3073	2.3116	2.3094	2.3137	2.3115	2.3158	2.3136	2.3179
$2\frac{7}{16}$	16	2.3698	83.4	2.3783	72.9	2.3698	2.3741	2.3719	2.3762	2.3740	2.3783	2.3761	2.3804
$2\frac{1}{2}$	4	2.2294	83.3	2.2594	74.1	2.2294	2.2444	2.2369	2.2519	2.2444	2.2594	2.2519	2.2669
$2\frac{1}{2}$	8	2.3647	83.3	2.3797	74.1	2.3647	2.3722	2.3684	2.3759	2.3722	2.3797	2.3760	2.3835
$2\frac{1}{2}$	12	2.4098	83.3	2.4198	74.1	2.4098	2.4148	2.4123	2.4173	2.4148	2.4198	2.4173	2.4223
$2\frac{1}{2}$	16	2.4323	83.4	2.4408	72.9	2.4323	2.4366	2.4344	2.4387	2.4365	2.4408	2.4386	2.4429
$2\frac{1}{2}$	20	2.4459	83.3	2.4537	71.3	2.4459	2.4498	2.4478	2.4517	2.4497	2.4537	2.4516	2.4556
$2\frac{5}{8}$	12	2.5348	83.3	2.5448	74.1	2.5348	2.5398	2.5373	2.5423	2.5398	2.5448	2.5423	2.5473
$2\frac{5}{8}$	16	2.5573	83.4	2.5658	72.9	2.5573	2.5616	2.5594	2.5637	2.5615	2.5658	2.5636	2.5679

[a] Based on Table 31. The differences between limits are equal to the minor-diameter tolerances given in Table 31 for lengths of engagement to and including $\frac{1}{3}D$. However, the minimum values for lengths of engagement greater than $\frac{1}{3}D$ and for sizes $\frac{1}{4}$ in. and larger are adjusted so that the difference between limits is never less than 0.0040 in. For diameter-pitch combinations other than those given in this table, the tolerances given in Table 31 should be similarly applied to determine hole-size limits.

[b] Based on length of engagement equal to the nominal diameter.

TABLE 37f—*Classes 1B, 2B, and 3B,*[a] *Recommended Hole-Size Limits Before Threading for Different Lengths of Engagement—UNC, UNF, UNEF, UN, NC, NF, NEF, and N Series*

DESIGNATION		MINOR-DIAMETER INTERNAL THREADS				RECOMMENDED HOLE-SIZE LIMITS FOR DIFFERENT LENGTHS OF ENGAGEMENT							
Thread size	Threads per inch	Minimum	Per cent basic thread height	Maximum[b]	Per cent basic thread height	To and including ⅓ *D*		Above ⅓ *D* to ⅔ *D*		Above ⅔ *D* to 1½ *D*		Above 1½ *D* to 3 *D*	
						Min	Max	Min	Max	Min	Max	Min	Max
2¾	4	2.4794	83.3	2.5094	74.1	2.4794	2.4944	2.4869	2.5019	2.4944	2.5094	2.5019	2.5169
2¾	8	2.6147	83.3	2.6297	74.1	2.6147	2.6222	2.6184	2.6259	2.6222	2.6297	2.6260	2.6335
2¾	12	2.6598	83.3	2.6698	74.1	2.6598	2.6648	2.6623	2.6673	2.6648	2.6698	2.6673	2.6723
2¾	16	2.6823	83.4	2.6908	72.9	2.6823	2.6866	2.6844	2.6887	2.6865	2.6908	2.6886	2.6929
2⅞	12	2.7848	83.3	2.7948	74.1	2.7848	2.7898	2.7873	2.7923	2.7898	2.7948	2.7923	2.7973
2⅞	16	2.8073	83.4	2.8158	72.9	2.8073	2.8116	2.8094	2.8137	2.8115	2.8158	2.8136	2.8179
3	4	2.7294	83.3	2.7594	74.1	2.7294	2.7444	2.7369	2.7519	2.7444	2.7594	2.7519	2.7669
3	8	2.8647	83.3	2.8797	74.1	2.8647	2.8722	2.8684	2.8759	2.8722	2.8797	2.8760	2.8835
3	12	2.9098	83.3	2.9198	74.1	2.9098	2.9148	2.9123	2.9173	2.9148	2.9198	2.9173	2.9223
3	16	2.9323	83.4	2.9408	72.9	2.9323	2.9366	2.9344	2.9387	2.9365	2.9408	2.9386	2.9429
3⅛	12	3.0348	83.3	3.0448	74.1	3.0348	3.0398	3.0373	3.0423	3.0398	3.0448	3.0423	3.0473
3⅛	16	3.0573	83.4	3.0658	72.9	3.0573	3.0616	3.0594	3.0637	3.0615	3.0658	3.0636	3.0679
3¼	4	2.9794	83.3	3.0094	74.1	2.9794	2.9944	2.9869	3.0019	2.9944	3.0094	3.0019	3.0169
3¼	8	3.1147	83.3	3.1297	74.1	3.1147	3.1222	3.1184	3.1259	3.1222	3.1297	3.1260	3.1335
3¼	12	3.1598	83.3	3.1698	74.1	3.1598	3.1648	3.1623	3.1673	3.1648	3.1698	3.1673	3.1723
3¼	16	3.1823	83.4	3.1908	72.9	3.1823	3.1866	3.1844	3.1887	3.1865	3.1908	3.1886	3.1929
3⅜	12	3.2848	83.3	3.2948	74.1	3.2848	3.2898	3.2873	3.2923	3.2898	3.2948	3.2923	3.2973
3⅜	16	3.3073	83.4	3.3158	72.9	3.3073	3.3116	3.3094	3.3137	3.3115	3.3158	3.3136	3.3179
3½	4	3.2294	83.3	3.2594	74.1	3.2294	3.2444	3.2369	3.2519	3.2444	3.2594	3.2519	3.2669
3½	8	3.3647	83.3	3.3797	74.1	3.3647	3.3722	3.3684	3.3759	3.3722	3.3797	3.3760	3.3835
3½	12	3.4098	83.3	3.4198	74.1	3.4098	3.4148	3.4123	3.4173	3.4148	3.4198	3.4173	3.4223
3½	16	3.4323	83.4	3.4408	72.9	3.4323	3.4366	3.4344	3.4387	3.4365	3.4408	3.4386	3.4429
3⅝	12	3.5348	83.3	3.5448	74.1	3.5348	3.5398	3.5373	3.5423	3.5398	3.5448	3.5423	3.5473
3⅝	16	3.5573	83.4	3.5658	72.9	3.5573	3.5616	3.5594	3.5637	3.5615	3.5658	3.5636	3.5679
3¾	4	3.4794	83.3	3.5094	74.1	3.4794	3.4944	3.4869	3.5019	3.4944	3.5094	3.5019	3.5169
3¾	8	3.6147	83.3	3.6297	74.1	3.6147	3.6222	3.6184	3.6259	3.6222	3.6297	3.6260	3.6335
3¾	12	3.6598	83.3	3.6698	74.1	3.6598	3.6648	3.6623	3.6673	3.6648	3.6698	3.6673	3.6723
3¾	16	3.6823	83.4	3.6908	72.9	3.6823	3.6866	3.6844	3.6887	3.6865	3.6908	3.6886	3.6929
3⅞	12	3.7848	83.3	3.7948	74.1	3.7848	3.7898	3.7873	3.7923	3.7898	3.7948	3.7923	3.7973
3⅞	16	3.8073	83.4	3.8158	72.9	3.8073	3.8116	3.8094	3.8137	3.8115	3.8158	3.8136	3.8179

[a] Based on Table 31. The differences between limits are equal to the minor-diameter tolerances given in Table 31 for lengths of engagement to and including ⅓ *D*. However, the minimum values for lengths of engagement greater than ¼ *D* and for sizes ¼ in. and larger are adjusted so that the difference between limits is never less than 0.0040 in. For diameter-pitch combinations other than those given in this table, the tolerances given in Table 31 should be similarly applied to determine hole-size limits.

[b] Based on length of engagement equal to the nominal diameter.

TABLE 37g—*Classes 1B, 2B, and 3B*,[a] *Recommended Hole-Size Limits Before Threading for Different Lengths of Engagement—UNC, UNF, UNEF, UN, NC, NF, NEF, and N Series*

DESIGNATION		MINOR-DIAMETER INTERNAL THREADS				RECOMMENDED HOLE-SIZE LIMITS FOR DIFFERENT LENGTHS OF ENGAGEMENT							
Thread size	Threads per inch	Minimum	Per cent basic thread height	Maximum[b]	Per cent basic thread height	To and including $\frac{1}{2}D$		Above $\frac{1}{2}D$ to $\frac{3}{4}D$		Above $\frac{3}{4}D$ to $1\frac{1}{2}D$		Above $1\frac{1}{2}D$ to $3D$	
						Min	Max	Min	Max	Min	Max	Min	Max
4	4	3.7294	83.3	3.7594	74.1	3.7294	3.7444	3.7369	3.7519	3.7444	3.7594	3.7519	3.7669
4	8	3.8647	83.3	3.8797	74.1	3.8647	3.8722	3.8684	3.8759	3.8722	3.8797	3.8760	3.8835
4	12	3.9098	83.3	3.9198	74.1	3.9098	3.9148	3.9123	3.9173	3.9148	3.9198	3.9173	3.9223
4	16	3.9323	83.4	3.9408	72.9	3.9323	3.9366	3.9344	3.9387	3.9365	3.9408	3.9386	3.9429
4¼	4	3.9794	83.3	4.0094	74.1	3.9794	3.9944	3.9869	4.0019	3.9944	4.0094	4.0019	4.0169
4¼	8	4.1147	83.3	4.1297	74.1	4.1147	4.1222	4.1184	4.1259	4.1222	4.1297	4.1260	4.1335
4¼	12	4.1598	83.3	4.1698	74.1	4.1598	4.1648	4.1623	4.1673	4.1648	4.1698	4.1673	4.1723
4¼	16	4.1823	83.4	4.1908	72.9	4.1823	4.1866	4.1844	4.1887	4.1865	4.1908	4.1886	4.1929
4½	4	4.2294	83.3	4.2594	74.1	4.2294	4.2444	4.2369	4.2519	4.2444	4.2594	4.2519	4.2669
4½	8	4.3647	83.3	4.3797	74.1	4.3647	4.3722	4.3684	4.3759	4.3722	4.3797	4.3760	4.3835
4½	12	4.4098	83.3	4.4198	74.1	4.4098	4.4148	4.4123	4.4173	4.4148	4.4198	4.4173	4.4223
4½	16	4.4323	83.4	4.4408	72.9	4.4323	4.4366	4.4344	4.4387	4.4365	4.4408	4.4386	4.4429
4¾	8	4.6147	83.3	4.6297	74.1	4.6147	4.6222	4.6184	4.6259	4.6222	4.6297	4.6260	4.6335
4¾	12	4.6598	83.3	4.6698	74.1	4.6598	4.6648	4.6623	4.6673	4.6648	4.6698	4.6673	4.6723
4¾	16	4.6823	83.4	4.6908	72.9	4.6823	4.6866	4.6844	4.6887	4.6865	4.6908	4.6886	4.6929
5	8	4.8647	83.3	4.8797	74.1	4.8647	4.8722	4.8684	4.8759	4.8722	4.8797	4.8760	4.8835
5	12	4.9098	83.3	4.9198	74.1	4.9098	4.9148	4.9123	4.9173	4.9148	4.9198	4.9173	4.9223
5	16	4.9323	83.4	4.9408	72.9	4.9323	4.9366	4.9344	4.9387	4.9365	4.9408	4.9386	4.9429
5¼	8	5.1147	83.3	5.1297	74.1	5.1147	5.1222	5.1184	5.1259	5.1222	5.1297	5.1260	5.1335
5¼	12	5.1598	83.3	5.1698	74.1	5.1598	5.1648	5.1623	5.1673	5.1648	5.1698	5.1673	5.1723
5¼	16	5.1823	83.4	5.1908	72.9	5.1823	5.1866	5.1844	5.1887	5.1865	5.1908	5.1886	5.1929
5½	8	5.3647	83.3	5.3797	74.1	5.3647	5.3722	5.3684	5.3759	5.3722	5.3797	5.3760	5.3835
5½	12	5.4098	83.3	5.4198	74.1	5.4098	5.4148	5.4123	5.4173	5.4148	5.4198	5.4173	5.4223
5½	16	5.4323	83.4	5.4408	72.9	5.4323	5.4366	5.4344	5.4387	5.4365	5.4408	5.4386	5.4429
5¾	8	5.6147	83.3	5.6297	74.1	5.6147	5.6222	5.6184	5.6259	5.6222	5.6297	5.6260	5.6335
5¾	12	5.6598	83.3	5.6698	74.1	5.6598	5.6648	5.6623	5.6673	5.6648	5.6698	5.6673	5.6723
5¾	16	5.6823	83.4	5.6908	72.9	5.6823	5.6866	5.6844	5.6887	5.6865	5.6908	5.6886	5.6929
6	8	5.8647	83.3	5.8797	74.1	5.8647	5.8722	5.8684	5.8759	5.8722	5.8797	5.8760	5.8835
6	12	5.9098	83.3	5.9198	74.1	5.9098	5.9148	5.9123	5.9173	5.9148	5.9198	5.9173	5.9223
6	16	5.9323	83.4	5.9408	72.9	5.9323	5.9366	5.9344	5.9387	5.9365	5.9408	5.9386	5.9429

[a] Based on Table 31. The differences between limits are equal to the minor-diameter tolerances given in Table 31 for lengths of engagement to and including $\frac{1}{2}D$. However, the minimum values for lengths of engagement greater than $\frac{1}{2}D$ and for sizes $\frac{1}{4}$ in. and larger are adjusted so that the difference between limits is never less than 0.0040 in. For diameter-pitch combinations other than those given in this table, the tolerances given in Table 31 should be similarly applied to determine hole-size limits.

[b] Based on length of engagement equal to the nominal diameter.

Dryseal Pipe Threads

SAE Standard

Report of Miscellaneous Division approved March 1921 and last revised by Screw Threads Technical Committee January 1951. Values in Table 1 conform to those in Table 9, Limits on Crest and Root of American Standard Pipe Threads, ASA B2.1-1945.

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[*This SAE Standard is primarily a system of pipe-thread designs which, if adhered to, will reduce the confusion experienced by some users and manufacturers. It is a design specification for thread truncation at crest and root to reduce possible interference and allow no clearance at these points. Corrections are also made in ⅛- and ¼-in. internal threads for a disproportionate number of threads for hand engagement and wrench take-up in the American (National) Standard Taper Pipe Thread (NPT).*

The other basic detail dimensions for external thread on pipe are derived from the Briggs formulas which have been adopted as the American Standard. The Briggs formulas did not provide for internal threads or gaging requirements and tolerance for making taper threaded joints. Gaging practice and tolerance were later standardized about 1913, with the adoption of the thin-ring gage and the truncation of the thread plug and ring gages to gage the flanks of the thread. The pitch-diameter tolerance for this gaging practice was plus or minus one turn (thread), the small end of the ring gage, when screwed on tight by hand, being within one turn either way of the small end of the external threaded product, and the gaging notch on the plug gage, when screwed in tight by hand, being within one turn either way of the large end or bottom of chamfer, if chamfered, of the internal threaded product.

Straight internal thread for assembly with taper external thread was later adopted for wrought-iron or wrought-steel couplings of the weight known as standard for ordinary pressures, as they were sufficiently ductile to adjust themselves to the taper external thread when properly screwed together.

With the adoption of the American Grease Fitting straight internal pipe-thread taps, which were given a pitch diameter equivalent to two threads below the hand engagement plane pitch diameter of the taper pipe thread (pitch diameter at the gaging notch, L_1 distance from the small end of taper threaded plug gage), the practice of shortening the pipe thread for economy of material and clearance became critical. Some manufacturers shortened the thread length at the small end and others at the large end. For use with thread lengths shortened at the small end, a new series of straight pipe taps, designated Intermediate, were adopted. These were given a pitch diameter equivalent to one half thread below the hand-engagement plane pitch diameter of the taper pipe thread.]

The following specifications cover the design and dimensions of pipe threads for automotive applications. They are based on the American (National) Standard Taper Pipe Thread and for full thread length conform in all respects to the Dryseal American (National) Standard Taper Pipe Thread and Dryseal American (National) Fuel Internal Straight Pipe Thread published in the latest revision of American Standard B2.1. The Short Dryseal Taper Pipe Thread is an SAE design exclusively, and the taper pipe thread conforms in all respects to the Dryseal American (National) Standard Taper Pipe Thread except in length of full thread which is reduced for economy of material and clearances.

Taper and Form of Thread—The angle between the sides of the thread is 60 deg when measured in an axial plane, and the line bisecting this angle is perpendicular to the axis for either taper or straight pipe threads.

The modification of thread form wherein the Dryseal American (National) Standard Taper Pipe Thread (NPTF) differs from the American (National) Standard (NPT) consists of a change in truncation of root and crest (see Table 1) to insure their contact before flanks engage. The elimination of clearance at crest and root prevents spiral leakage and renders joints pressure-tight without lubricant or sealer. However, a lubricant may be used to prevent galling during make-up of joints, unless its use is functionally objectionable.

The root and crest of threads as specified are flat, although commercially manufactured threads appear rounded. Threads are acceptable when crests and roots lie within limits of Table 1.

The taper of taper pipe thread shall be 1 in 16, or 0.75 in. per ft, measured on the diameter and along the axis with a tolerance of $\pm 1/16$ in.

Diameter and Length of Thread—Basic diameter and length

of thread for different thread sizes, tabulated in Tables 2, 3, and 4, are based on the following formulas:

Basic pitch diameter of thread at small end of external thread (NPTF)

$$E_0 = D - (0.05D + 1.1)\,p$$

Basic pitch diameter of thread at small end of external thread (PTF—SAE Short)

$$E_0 \text{ Short} = D - (0.05D + 1.037)\,p$$

Basic pitch diameter of thread at large end of internal thread (NPTF)

$$E_1 = E_0 + (0.0625 \times L_1 \text{ Basic})$$

Basic pitch diameter of thread at large end of internal thread (PTF—SAE Short)

$$E_1 \text{ Short} = E_0 + (0.0625 \times L_1 \text{ Short})$$

Basic length of external full thread (NPTF)

$$L_2 = (0.8D + 6.8)\,p$$

Basic length of external full thread (PTF—SAE Short)

$$L_2 \text{ Short} = (0.8D + 5.8)\,p$$

Basic length of internal full thread (NPTF) = L_1 Basic + L_3

Basic length of internal full thread (PTF—SAE Short) = L_1 Short + L_3

where D = outside diameter of pipe
p = pitch of thread in inches

The length of full thread includes only threads of correct form at crest and root.

The length of effective thread includes approximately two threads slightly imperfect at the crest, such as obtained on standard O D pipe.

Designation Symbol Abbreviations—National or American (N); Pipe (P); Taper (T); Straight (S); Fuel or Dryseal (F); Intermediate (I).

Thread Series Designation Symbols—The identification symbols adopted to designate the various thread series are:

Dryseal American (National) Standard Taper Pipe Thread (NPTF);

Dryseal American (National) Fuel Internal Straight Pipe Thread (NPSF);

Dryseal American (National) Intermediate Internal Straight Pipe Thread (NPSI);

Dryseal SAE Short Taper Pipe Thread (PTF—SAE Short).

Method of Designating a Pipe Thread—The method of designating a pipe thread by means of symbols is by the use of the initial letters of the thread series preceded by the nominal size and thread form (if Dryseal), all in Arabic characters.

Examples are given below:

⅛–27 Dryseal NPTF; ⅛–27 Dryseal PTF—SAE Short; ⅛–27 Dryseal NPSF; ⅛–27 Dryseal NPSI.

Tolerance—Threaded product tolerances applying to the use of various gaging methods and gages are given in Appendix A. For gaging tolerance of Dryseal American (National) Standard Taper Pipe Thread (NPTF), Dryseal SAE Short Taper Pipe Thread (PTF—SAE Short), Dryseal American (National) Fuel Internal Straight Pipe Thread (NPSF), and Dryseal American (National) Intermediate Internal Straight Pipe Thread (NPSI) using the basic-notch gage visual or position method, see Appendix A, Section I; using the limit gage or step-limit method, see Appendix A, Section II; and using the turns-engagement method, see Appendix A, Section III. Working gages shall not be used when worn beyond the basic dimensions by more than ½ turn (thread). Proper allowance shall be made for any variation from basic when using a gage.

Dryseal American (National) Standard Taper Pipe Thread (NPTF)—External and internal taper pipe threads are used for pipe joints in practically every type of service. They are generally conceded to be superior for strength and seal. In hard or brittle material without heavy sections, the internal taper pipe thread reduces trouble from fracture. Hand-tight engagement and wrench take-up for Dryseal taper pipe threads are proportionate for all sizes. Standard internal taper pipe thread when used with lubrication fittings, which have external thread with shorter length of full thread than SAE Short, should be held closer than standard tolerance toward the minimum pitch diameter.

For specifications covering NPTF, see Table 2. For gaging methods, gages, cut thread blanks, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.

Dryseal SAE Short External Taper Pipe Thread (PTF—SAE Short)—At purchaser's option, external taper pipe thread shorter than standard length may be specified, although it is the consensus of manufacturer and user opinion that trouble-free assembly and pressure-tight joints without lubricant or sealer cannot be assured unless full length threads are used. Where short thread length is specified, shortening shall be by eliminating one thread at the small end. Any further shortening shall be by reducing the allowance for chamfer and shoulder clearance for dies or chasers. While products with short external taper thread are primarily intended for assembly with Dryseal American (National) Intermediate Internal Straight Pipe Thread (NPSI), they will assemble with the Dryseal American (National) Standard Internal Taper Pipe Thread (NPTF). Hand engagement with the short external thread and full-length internal thread is one turn (thread) less than with full-length external thread. For specifications covering PTF–SAE Short External Thread, see Table 3. For gaging methods, gages, cut thread blanks, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.

Dryseal SAE Short Internal Taper Pipe Thread (PTF—SAE Short)—At purchaser's option, internal taper pipe thread shorter than standard length may be specified although it is the consensus of manufacturer and user opinion that trouble-free assembly and pressure-tight joints without lubricant or sealer cannot be assured unless full length threads are used. Where short thread length is specified, shortening shall be by eliminating one thread at the large end. Depth of tap drill is shortened by reducing the projection of the tap through the ring gage for SAE Short taps. Products with short internal threads are primarily intended for assembly with Dryseal American (National) Standard External Taper Pipe Thread (NPTF). *They are not designed for and may not at extreme tolerances assemble with SAE Short External Thread in all cases.* The hand engagement with short internal thread and full-length external thread is one turn (thread) less than with full-length internal thread. When used with lubrication fittings, which have external thread at small end gaged similar to SAE Short, the internal thread or the ex-

Truncation—Dryseal American (National) Standard External and Internal Pipe Threads

For pressure-tight joints without lubricant or sealer

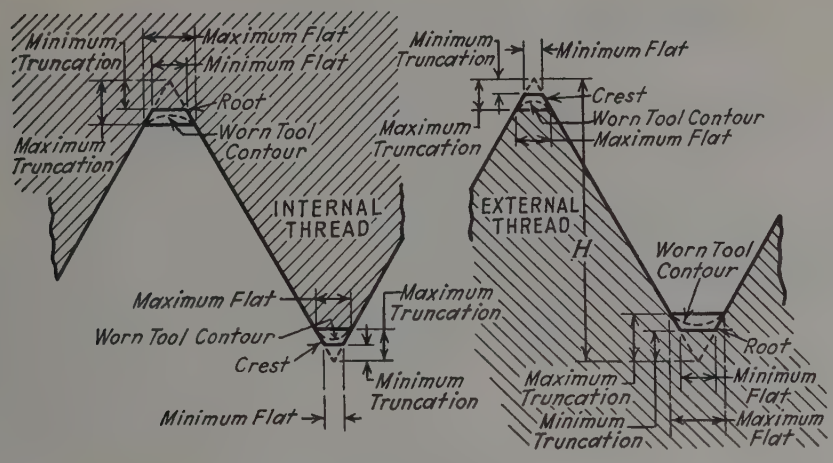


TABLE 1—*Limits on Crest and Root Truncation*

THREADS PER INCH		DEPTH OF SHARP-V THREAD, H	TRUNCATION				EQUIVALENT WIDTH OF FLAT[a]			
			Minimum		Maximum		Minimum		Maximum	
		In.	Formula	In.	Formula	In.	Formula	In.	Formula	In.
27	Crest	0.03208	$0.047p$	0.0017	$0.094p$	0.0035	$0.054p$	0.0020	$0.108p$	0.0040
	Root		$0.094p$	0.0035	$0.140p$	0.0052	$0.108p$	0.0040	$0.162p$	0.0060
18	Crest	0.04811	$0.047p$	0.0026	$0.078p$	0.0043	$0.054p$	0.0030	$0.090p$	0.0050
	Root		$0.078p$	0.0043	$0.109p$	0.0061	$0.090p$	0.0050	$0.126p$	0.0070
14	Crest	0.06186	$0.036p$	0.0026	$0.060p$	0.0043	$0.042p$	0.0030	$0.070p$	0.0050
	Root		$0.060p$	0.0043	$0.085p$	0.0061	$0.070p$	0.0050	$0.098p$	0.0070
11½	Crest	0.07531	$0.040p$	0.0035	$0.060p$	0.0052	$0.046p$	0.0040	$0.069p$	0.0060
	Root		$0.060p$	0.0052	$0.090p$	0.0078	$0.069p$	0.0060	$0.103p$	0.0090
8	Crest	0.10825	$0.042p$	0.0052	$0.055p$	0.0069	$0.048p$	0.0060	$0.064p$	0.0080[b]
	Root		$0.055p$	0.0069	$0.076p$	0.0095	$0.064p$	0.0080	$0.088p$	0.0110

[a] The major diameter of plug gages and minor diameter of ring gages used for gaging dryseal threads shall be truncated an amount sufficient to produce a flat width as shown in Appendix A, Tables A1-1 to A12-1 inclusive.
[b] There is reason to doubt the correctness of the 8-pitch flat widths because of the volume of metal to be displaced.

ternal thread or both should be held closer than standard tolerance, the internal thread toward the maximum pitch diameter and the external thread toward the minimum pitch diameter, to provide a minimum of one-turn hand engagement.

For specifications covering PTF—SAE Short Internal Thread, see Table 4. For gaging methods, gages, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.

Straight Pipe Threads—Assemblies in which both components have taper pipe threads are generally conceded to be superior for strength and seal. Assemblies with straight internal pipe threads and taper external pipe threads are frequently more advantageous than all taper assemblies, particularly in automotive and other mass-production industries where economy and rapid production are paramount considerations. Assemblies in which both components have straight pipe threads are not made with Dryseal pipe threads. These should be made with mechanical straight pipe threads and a gasket drawn down against a shoulder.

Straight internal pipe thread for assembly with full-length external taper pipe thread (NPTF) on products should be tapped with Dryseal American (National) Fuel Straight Pipe Taps (NPSF). This tap, having been adjusted on ⅛- and ¼-in. sizes to obtain threads for hand engagement and wrench take-up proportionate to all other sizes, supersedes the American (National) Grease Fitting Tap (NPSG). This thread (NPSF) is primarily intended for relatively soft or ductile materials which will adjust themselves to the taper external thread when properly screwed together. It may be used in hard or brittle materials with heavy sections for assembly with full-length external taper pipe thread. It is also sometimes used to limit the depth of assembly of the small end of external taper pipe thread. When used with lubrication fittings, which have external thread at small end gaged similar to SAE Short, the internal thread or the external thread or both should be held closer than standard tolerance, the internal thread toward the maximum pitch diameter and the

Dryseal American (National) Standard Taper Pipe Thread (NPTF)

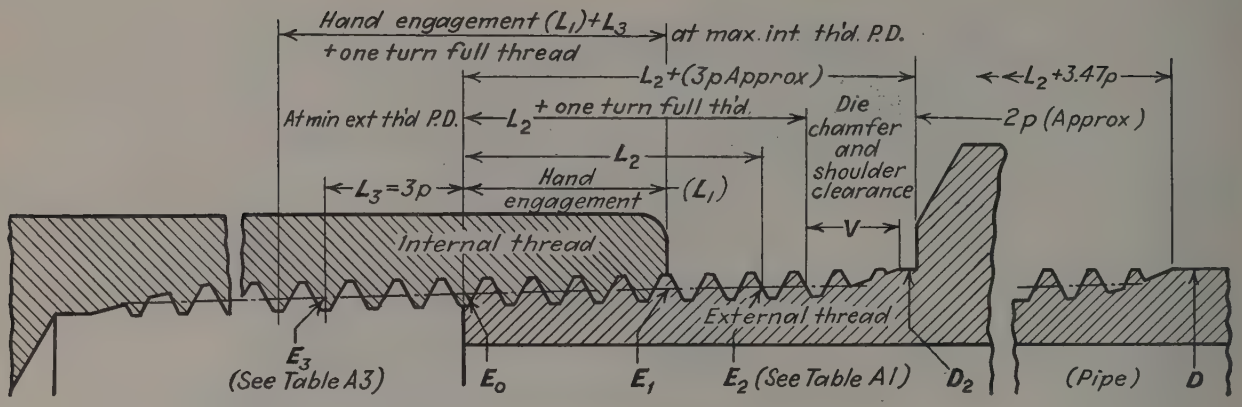


TABLE 2—*Basic Dimensions of Dryseal American (National) Standard Taper Pipe Thread*[a]

NPTF SIZE	PITCH, p	PD AT END OF EXT THREAD E_0	PD AT END OF INT THREAD, E_1	HAND ENGAGEMENT, L_1		LENGTH OF FULL THREAD, L_2		VANISH THREADS V PLUS FULL THREAD TOLER PLUS SHOULDER CLEAR. ($V + 1p + \frac{1}{2}p$)		SHOULDER LENGTH $L_2 + (3\ p$ APPROX)	EXTERNAL THREAD FOR DRAW ($L_2 - L_1$)		LENGTH OF INTERNAL FULL THREAD ($L_1 + L_3$)		OUTSIDE DIAMETER OF FITTING, D_2	OUTSIDE DIAMETER OF PIPE, D
	in.	in.	in.	in.	thd	in.	thd	in.	thd	in.	in.	thd	in.	thd	in.	in.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1/16–27	0.03704	0.27118	0.28118	0.160	4.32	0.2611	7.05	0.1139	3.075	0.3750	0.1011	2.73	0.2711	7.32	0.315	0.3125
1/8 –27	0.03704	0.36351	0.37360	0.1615	4.36	0.2638	7.12	0.1112	3.072	0.3750	0.1023	2.76	0.2726	7.36	0.407	0.405
1/4 –18	0.05556	0.47739	0.49163	0.2278	4.10	0.4018	7.23	0.1607	2.892	0.5625	0.1740	3.13	0.3945	7.10	0.546	0.540
3/8 –18	0.05556	0.61201	0.62701	0.240	4.32	0.4078	7.34	0.1547	2.791	0.5625	0.1678	3.02	0.4067	7.32	0.681	0.675
1/2 –14	0.07143	0.75843	0.77843	0.320	4.48	0.5337	7.47	0.2163	3.028	0.7500	0.2137	2.99	0.5343	7.48	0.850	0.840
3/4 –14	0.07143	0.96768	0.98887	0.339	4.75	0.5457	7.64	0.2043	2.860	0.7500	0.2067	2.89	0.5533	7.75	1.060	1.050
1 –11½	0.08696	1.21363	1.23863	0.400	4.60	0.6828	7.85	0.2547	2.929	0.9375	0.2828	3.25	0.6609	7.60	1.327	1.315
1¼ –11½	0.08696	1.55713	1.58338	0.420	4.83	0.7068	8.13	0.2620	3.013	0.9688	0.2868	3.30	0.6809	7.83	1.672	1.660
1½ –11½	0.08696	1.79609	1.82234	0.420	4.83	0.7235	8.32	0.2765	3.180	1.0000	0.3035	3.49	0.6809	7.83	1.912	1.900
2 –11½	0.08696	2.26902	2.29627	0.436	5.01	0.7565	8.70	0.2747	3.159	1.0312	0.3205	3.69	0.6969	8.01	2.387	2.375
2½ –8	0.12500	2.71953	2.76216	0.682	5.46	1.1374	9.10	0.3781	3.025	1.5156	0.4555	3.64	1.0570	8.46	2.893	2.875
3 –8	0.12500	3.34063	3.38850	0.766	6.13	1.2000	9.60	0.3781	3.025	1.5781	0.4340	3.47	1.1410	9.13	3.518	3.500

[a] See general specifications preceding tables.
For gaging methods, gages, cut thread blanks, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.

external thread toward the minimum pitch diameter, to provide a minimum of one-turn hand engagement.

For specifications covering NPSF, see Table 5. For gaging methods, gages, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.

Straight internal pipe thread for assembly with short-length external taper pipe thread (PTF—SAE Short) on products, should be tapped with Dryseal American (National) Intermediate Straight Pipe Taps (NPSI). This tap, having been adjusted on 1/8- and 1/4-in. sizes to obtain threads for hand engagement and wrench take-up proportionate to all other sizes, supersedes the American (National) Coupling Straight Tap (NPSC). This thread (NPSI) is primarily intended for assembly with Dryseal SAE Short External Taper Pipe Thread (PTF—SAE Short) but will assemble with the Dryseal American (National) Standard External Taper Pipe Thread (NPTF). It should not be used with lubrication fittings which have shorter length of full thread than SAE Short. This thread (NPSI) is used extensively in hard or brittle materials of heavy section where there is little give in assembly with external taper pipe thread. For specifications covering NPSI, see Table 6. For gaging methods, gages, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.

(*Appendix A follows Table 6.*)

Dryseal SAE Short External Taper Pipe Thread (PTF—SAE Short External)

For assembly with Dryseal American (National) Intermediate Internal Straight (Table 6) or Dryseal American (National) Standard Taper (Table 2) Pipe Threads

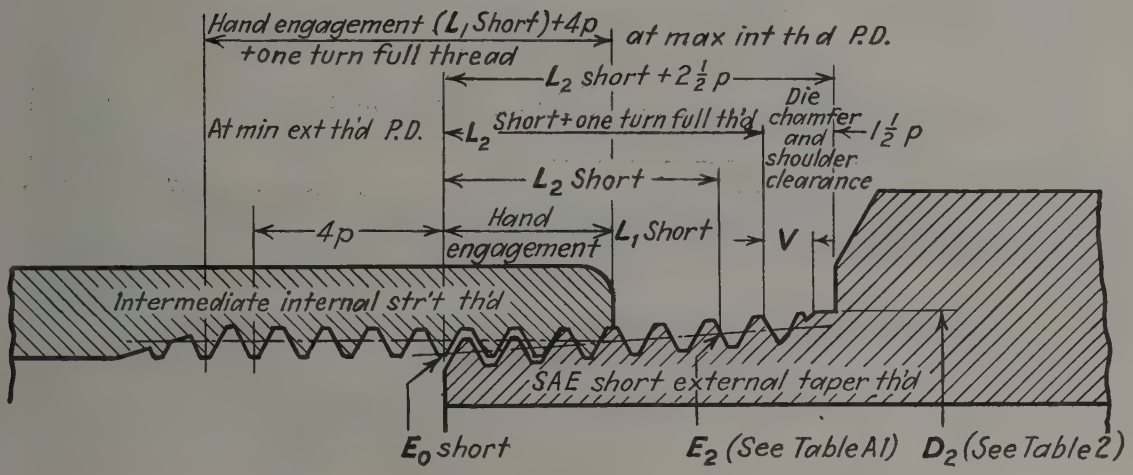


TABLE 3—*Basic Dimensions of Dryseal SAE Short External Taper Pipe Thread*[a]

PTF—SAE SHORT SIZE	PITCH, p	PD AT END OF EXT THREAD, E_0 SHORT	L_1		HAND ENGAGEMENT, L_1 SHORT		LENGTH OF FULL THREAD, L_2 SHORT		VANISH THREADS V PLUS FULL THREAD TOLER PLUS SHOULDER CLEAR. ($V + 1p + ½p$)		MINIMUM SHOULDER LENGTH (L_2 SHORT $+ 2½p$)	EXTERNAL THREAD FOR DRAW (L_2 SHORT $-$ L_1 SHORT)		LENGTH OF INTERNAL FULL THREAD (L_1 SHORT $+ 4p$)	
	in.	in.	in.	thd	in.	thd	in.	thd	in.	thd	in.	in.	thd	in.	thd
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1/16–27	0.03704	0.27349	0.160	4.32	0.1230	3.32	0.2241	6.05	0.0926	2.50	0.3167	0.1011	2.73	0.2711	7.32
⅛ –27	0.03704	0.36582	0.1615	4.36	0.1244	3.36	0.2268	6.12	0.0926	2.50	0.3194	0.1024	2.76	0.2726	7.36
¼ –18	0.05556	0.48086	0.2278	4.10	0.1722	3.10	0.3462	6.23	0.1389	2.50	0.4851	0.1740	3.13	0.3945	7.10
⅜ –18	0.05556	0.61548	0.240	4.32	0.1844	3.32	0.3522	6.34	0.1389	2.50	0.4911	0.1678	3.02	0.4067	7.32
½ –14	0.07143	0.76289	0.320	4.48	0.2486	3.48	0.4623	6.47	0.1786	2.50	0.6409	0.2137	2.99	0.5343	7.48
¾ –14	0.07143	0.97214	0.339	4.75	0.2676	3.75	0.4743	6.64	0.1786	2.50	0.6528	0.2067	2.89	0.5533	7.75
1 –11½	0.08696	1.21906	0.400	4.60	0.3130	3.60	0.5958	6.85	0.2174	2.50	0.8132	0.2828	3.25	0.6609	7.60
1¼ –11½	0.08696	1.56256	0.420	4.83	0.3330	3.83	0.6198	7.13	0.2174	2.50	0.8372	0.2868	3.30	0.6809	7.83
1½ –11½	0.08696	1.80152	0.420	4.83	0.3330	3.83	0.6365	7.32	0.2174	2.50	0.8539	0.3035	3.49	0.6809	7.83
2 –11½	0.08696	2.27445	0.436	5.01	0.3490	4.01	0.6695	7.70	0.2174	2.50	0.8869	0.3205	3.69	0.6969	8.01
2½ –8	0.12500	2.72734	0.682	5.46	0.5570	4.46	1.0125	8.10	0.3125	2.50	1.3250	0.4555	3.64	1.0570	8.46
3 –8	0.12500	3.34844	0.766	6.13	0.6410	5.13	1.0750	8.60	0.3125	2.50	1.3875	0.4340	3.47	1.1410	9.13

[a] See general specifications preceding tables.
For gaging methods, gages, cut thread blanks, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.

Dryseal SAE Short Internal Taper Pipe Thread (PTF—SAE Short Internal)

For assembly with American (National) Standard External Taper Pipe Thread (Table 2)

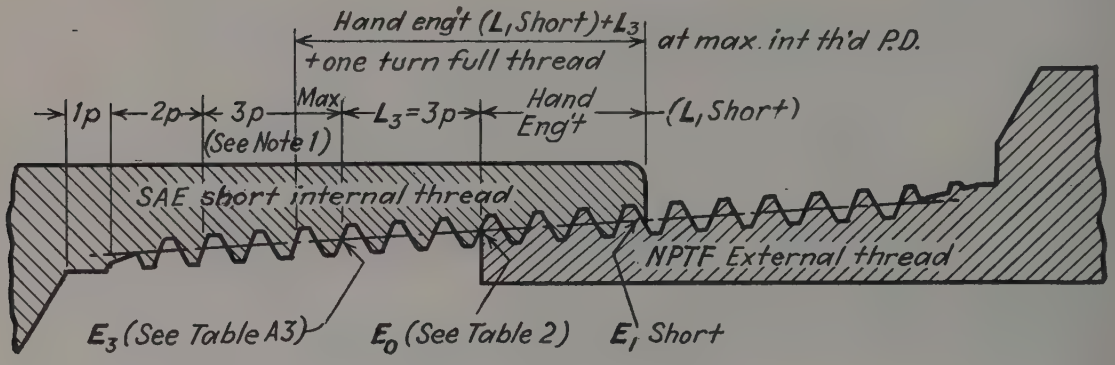


TABLE 4—*Basic Dimensions of Dryseal SAE Short Internal Taper Pipe Thread*[a]

PTF—SAE SHORT SIZE	PITCH, p	PD AT END OF INT THREAD E_1 SHORT (Note 2)	L_1		HAND ENGAGEMENT L_1 SHORT		LENGTH OF INTERNAL FULL THREAD (L_1 SHORT + L_2)		HOLE DEPTH FOR SAE SHORT TAP (Table B5)
	in.	in.	in.	thd	in.	thd	in.	thd	in.
1	2	3	4	5	6	7	8	9	10
1/16–27	0.03704	0.27887	0.160	4.32	0.1230	3.32	0.2341	6.32	0.4564
1/8 –27	0.03704	0.37129	0.1615	4.36	0.1244	3.36	0.2356	6.36	0.4578
1/4 –18	0.05556	0.48815	0.2278	4.10	0.1722	3.10	0.3389	6.10	0.6722
3/8 –18	0.05556	0.62354	0.240	4.32	0.1844	3.32	0.3511	6.32	0.6844
1/2 –14	0.07143	0.77397	0.320	4.48	0.2486	3.48	0.4629	6.48	0.8915
3/4 –14	0.07143	0.98441	0.339	4.75	0.2676	3.75	0.4819	6.75	0.9105
1 –11½	0.08696	1.23320	0.400	4.60	0.3130	3.60	0.5749	6.60	1.0956
1¼ –11½	0.08696	1.57795	0.420	4.83	0.3330	3.83	0.5949	6.83	1.1156
1½ –11½	0.08696	1.81691	0.420	4.83	0.3330	3.83	0.5949	6.83	1.1156
2 –11½	0.08696	2.29084	0.436	5.01	0.3490	4.01	0.6109	7.01	1.1316
2½ –8	0.12500	2.75435	0.682	5.46	0.5570	4.46	0.9320	7.46	1.6820
3 –8	0.12500	3.38069	0.766	6.13	0.6410	5.13	1.0160	8.13	1.7660

[a] See general specifications preceding tables.
For gaging methods, gages, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.

Dryseal American (National) Standard Fuel Internal Straight Pipe Thread (NPSF)

For assembly with Dryseal American (National) Standard External Taper Pipe Thread (Table 2)

TABLE 5—*Dryseal American (National) Standard Fuel Internal Straight Pipe Thread Limits*[a]

NPSF SIZE	PITCH DIAMETER[b]		MINOR DIAMETER[c]	DESIRED MINIMUM LENGTH OF FULL THREAD	
	Max[d,e]	Min[e,f]	Min	in.	Thd
1	2	3	4	5	6
1/16–27	0.2803	0.2768	0.2482	5/16	8.44
1/8 –27	0.3727	0.3692	0.3406	5/16	8.44
1/4 –18	0.4904	0.4851	0.4422	15/32	8.44
3/8 –18	0.6257	0.6205	0.5776	1/2	9.00
1/2 –14	0.7767	0.7700	0.7133	21/32	9.19
3/4 –14	0.9872	0.9805	0.9238	21/32	9.19
1 –11½	1.2365	1.2284	1.1600	25/32	8.98

[a] See general specifications preceding tables.
For gaging methods, gages, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.
[b] The pitch diameter of the tapped hole as indicated by the taper plug gage is slightly larger than the values given due to the gage having to enter approximately 3/8 turn to engage first full thread.
[c] As the Dryseal American (National) Standard pipe thread form is maintained, the major and minor diameters of the internal thread vary with the pitch diameter.
[d] Col 2 is the same as the E_1 pitch diameter of thread at large end of internal thread (Table 2) minus (small) 3/8 thread taper.
[e] Taps specified in Table B6 produce tapped holes to the above limits in cast iron, steel, and brass. In zinc and similar soft metals, they produce tapped holes approximately 0.001 smaller. Plug-gage turns engagement should be reduced accordingly.
[f] Col 3 is Col 2 reduced by 1½ turns.

Dryseal American (National) Intermediate Internal Straight Pipe Thread (NPSI)

For assembly with Dryseal SAE Short External Taper (Table 3) or American (National) Standard Taper Pipe Thread (Table 2)

TABLE 6—*Dryseal American (National) Intermediate Internal Straight Pipe Thread Limits*[a]

NPSI SIZE	PITCH DIAMETER[b]		MINOR DIAMETER[c]	DESIRED MINIMUM LENGTH OF FULL THREAD	
	Max.[d,e]	Min.[e,f]	Min	In.	Thd
1	2	3	4	5	6
1/16–27	0.2826	0.2711	0.2505	5/16	8.44
1/8 –27	0.3750	0.3715	0.3429	5/16	8.44
1/4 –18	0.4938	0.4886	0.4457	15/32	8.44
3/8 –18	0.6292	0.6240	0.5811	1/2	9.00
1/2 –14	0.7812	0.7745	0.7180	21/32	9.19
3/4 –14	0.9917	0.9850	0.9283	21/32	9.19
1 –11½	1.2420	1.2338	1.1655	25/32	8.98

[a] See general specifications preceding tables.
For gaging methods, gages, taps, drilled hole sizes, hole depths, and full thread lengths, see Appendixes A and B.
[b] The pitch diameter of the tapped hole as indicated by the taper plug gage is slightly larger than the values given due to the gage having to enter approximately 3/8 turn to engage first full thread.
[c] As the Dryseal American (National) Standard pipe thread form is maintained, the major and minor diameters of the internal thread vary with the pitch diameter.
[d] Col 2 is the E_1 pitch diameter of thread at large end of internal thread (Table 2) plus (large) 5/8 thread taper.
[e] Taps specified in Table B7 produce tapped holes to the above limits in cast iron, steel, and brass. In zinc and similar soft metals, they produce tapped holes approximately 0.001 smaller. Plug-gage turns engagement should be reduced accordingly.
[f] Col 3 is Col 2 reduced by 1½ turns.

Appendix A—Dryseal Pipe-Thread Gaging

General—There are three accepted methods of checking Dryseal pipe threads with threaded plug and ring gages. The methods separately described in the following sections are:

Section I—Position method with basic-notch gages.

Section II—Limit method with step-limit gages.

Section III—Turns-engagement method with either basic-notch or limit-notch gages.

All methods of gaging external Dryseal threads involve the use of two ring thread gages, the (L_1) thin-ring thread gage for checking the pitch diameter over the hand engagement or (L_1) thread length and the (L_2) full-thread ring gage for checking the pitch diameter over the full thread length to insure adequate threads for wrench tightening.

All methods of gaging internal Dryseal threads involve the use of two plug thread gages, the (L_1) plug thread gage for checking the pitch diameter over the hand engagement or (L_1) thread length and the (L_3) plug thread gage for checking pitch diameter of the thread beyond the hand engagement length.

As indicated in the separate descriptions of the various gaging methods, coordination of the two ring thread gages for external threads and coordination of the two plug thread gages for internal threads control and check thread taper. The gages cannot be correlated, however, for external threads of minimum PD or internal threads of maximum PD unless the length of the threads is one thread longer than basic full thread length.

The threads of tools and the threads of a percentage of the product or casts in the case of internal threads should be projected as a check on thread form and truncation. Although projection is strongly recommended, the truncation at major diameter of internal thread and minor diameter of external thread may be checked respectively with special plug and ring gages with thread angle reduced to clear the flank of the threads; and the truncation at minor diameter of internal taper thread and major diameter of external taper thread may be checked respectively with plain taper plug gages and plain taper ring gages. Internal straight thread truncation at minor diameter may be checked with plain plug gages.

Section I—Position Method of Gaging with Basic Notch Gages

The position method of gaging Dryseal threads with plug thread and ring thread gages is a visual check of the position of the gages in relation to the product. It involves estimating the position of a notch or step on the thread gages in relation to the gaging point of the product within the allowable tolerance.

While the method is the same as that used for years past in checking conventional pipe threads without the Dryseal feature, the gages are different with respect to truncation of threads, the crests of the threads at the minor diameter of the ring gages and the major diameter of the plug gages being truncated to a greater extent to clear the increased truncation of the product thread. Another distinction is that the Dryseal (L_2) ring is counterbored larger than the thread diameter at the small end a distance equal to the (L_1) thread length minus one pitch. Conventional rings and plugs, however, may be converted to Dryseal by grinding the crests to conform with the width of flats specified for Dryseal gages, and grinding a counterbore in the (L_2) ring gage.

The gages are turned or screwed hand-tight into or onto the threaded product, the position of the gage notch in relation to the product reference point being noted to determine whether the standoff exceeds the allowable tolerance. Allowance must be made for excessive chamfer at the small end of external threads and the large end of internal threads, the product reference point in the first instance being the beginning of the first thread on the chamfer, and in the second instance being the intersection of the pitch diameter cone and the chamfer cone.

External Threads—Dryseal American (National) Standard External Taper Pipe Threads (NPTF) are gaged with the NPTF (L_1) basic notch Dryseal ring thread gages (Table A1) and the NPTF (L_2) basic-notch Dryseal ring thread gages (Table A1). Threads are within the allowable tolerance when the product reference point is flush with the gage reference point within a tolerance of plus (small) one turn, minus (large) one turn. As a check on taper, the (L_1) and (L_2) ring thread gages shall gage the same within ½ turn.

Dryseal SAE Short External Taper Pipe Threads PTF—SAE Short, which are one thread shorter at the small end than standard full thread length, are gaged with the NPTF (L_1) basic-notch Dryseal ring thread gages (Table A1) and the NPTF (L_2) basic-notch Dryseal ring thread gages (Table A1). Threads are within the allowable tolerance when the product reference point is flush with the gage reference point within a tolerance of plus zero, minus (large) 1½ turns. As a check on taper, the (L_1) and (L_2) ring thread gages shall gage the same within ½ turn.

Internal Threads—Dryseal American (National) Standard Internal Taper Pipe Threads (NPTF) are gaged with the NPTF (L_1) basic-notch Dryseal plug thread gages (Table A2) and the NPTF (L_3) basic-notch Dryseal plug gages (Table A3). Threads are within the allowable tolerance when the product reference point is flush with the gage notch within the following tolerances:

Plus (large) 1 turn, minus (small) 1 turn, for all sizes except ⅛ and ¼ in.

Plus (large) ½ turn, minus (small) 1½ turns, for ⅛-in. size.

Plus (large) 1½ turns, minus (small) ½ turn for ¼-in. size.

As a check on taper, the (L_1) and the (L_3) plug thread gages shall gage the same with relation to their respective notches within ½ turn.

Dryseal SAE Short Internal Taper Pipe Threads PTF—SAE Short, which are one thread shorter at the large end than standard full thread length, are gaged with the NPTF (L_1) basic-notch Dryseal plug thread gages (Table A2) and the NPTF (L_3) basic-notch Dryseal plug thread gages (Table A3). Threads are within the allowable tolerance when the product reference point is flush with the gage notch within the following tolerances:

Plus (large) 0 turns, minus (small) 1½ turns, for all sizes except ⅛ and ¼ in.

Minus (small) ½ turn, minus (small) 2 turns for the ⅛-in. size.

Plus (large) ½ turn, minus (small) 1 turn for the ¼-in. size.

As a check on taper, the (L_1) and the (L_3) gages shall check the same with relation to their respective notches within ½ turn.

Dryseal American (National) Standard Fuel Internal Straight Pipe Threads (NPSF) are gaged with the NPTF (L_1) basic-

notch Dryseal plug thread gages (Table A2). Threads are within the allowable tolerance when the product reference point is flush with the gage notch within the following tolerances:

Plus (large) 0 turns, minus (small) 1½ turns for all sizes except ⅛ and ¼ in.

Minus (small) ½ turn, minus (small) 2 turns, for the ⅛-in. size.

Plus (large) ½ turn, minus (small) 1 turn, for the ¼-in. size.

As depth gages without regard to gage notches, any of the (L_3) Dryseal plug thread gages may be used to check the full thread length of internal straight pipe threads.

Dryseal American (National) Standard Intermediate Internal Straight Pipe Threads (NPSI) are gaged with the NPTF (L_1) basic-notch Dryseal plug thread gages (Table A2). Threads are within the allowable tolerance when the product reference point is flush with the gage notch within the following tolerances:

Plus (large) 1 turn, minus (small) ½ turn, for all sizes except the ⅛ and ¼ in.

Plus (large) ½ turn, minus (small) 1 turn, for the ⅛-in. size.

Plus (large) 1½ turns, minus (small) 0 turns for the ¼-in. size.

As depth gages without regard to gage notches, any of the (L_3) Dryseal plug thread gages may be used to check the full thread length of internal straight pipe threads.

Section II—Limit Method of Gaging with Step-Limit Gages

The limit-gage or step-limit method of checking threaded product with plug thread and ring thread gages is a visual check of the position of the gages in relation to the product. Plug and ring gages with maximum and minimum limit notches are provided for the different thread types: NPTF, PTF—SAE Short, NPSF, and NPSI. The location of the limit notches on the ⅛- and ¼-in. plugs eliminates the necessity for gaging correction.

The gages are turned or screwed hand-tight into or onto the threaded product, the position of the product reference point in relation to the limit notches on the gage being noted. Allowance must be made for excessive chamfer at the small end of external threads and the large end of internal threads, the product reference point in the first instance being the beginning of the first thread on the chamfer, and in the second instance being the intersection of the pitch diameter cone and the chamfer cone.

External Threads—Dryseal American (National) Standard External Taper Pipe Threads (NPTF) are gaged with the NPTF (L_1) step-limit Dryseal ring thread gages (Table A4) and the NPTF (L_2) step-limit Dryseal ring thread gages (Table A5). Threads are within the allowable tolerance when the product reference point is on or between the limit notches. As a check on taper, the (L_1) and the (L_2) Dryseal ring thread gages shall gage the same in relation to their respective notches within ½ turn.

Dryseal SAE Short External Taper Pipe Threads PTF—SAE Short, which are one thread shorter at the small end than standard full thread length, are gaged with the PTF—SAE (L_1 Short) step-limit Dryseal ring thread gages (Table A8) and the PTF—SAE (L_2 Short) step-limit ring thread gages (Table A9). Threads are within the allowable tolerance when the product reference point is on or between the limit notches. As a check on taper, the (L_1 Short) and the (L_2 Short) Dryseal ring thread gages shall gage the same with relation to their respective notches within ½ turn.

Internal Threads—Dryseal American (National) Standard Internal Taper Pipe Threads (NPTF) are gaged with the NPTF (L_1) step-limit Dryseal plug thread gages (Table A6) and the NPTF (L_3) step-limit Dryseal plug thread gages (Table A7). Threads are within the allowable tolerance when the product reference point is on or between the limit notches. As a check on taper, the (L_1) and (L_3) Dryseal plug thread gages shall gage the same with relation to their respective notches within ½ turn.

Dryseal SAE Short Internal Taper Pipe Threads PTF—SAE Short, which are one thread shorter at the large end than standard full thread length, are gaged with the PTF—SAE (L_1 Short) step-limit Dryseal plug thread gages (Table A10) and the PTF—SAE (L_3 Short) step-limit Dryseal plug thread gages (Table A11). Threads are within the allowable tolerance when the product reference point is on or between the limit notches. As a check on taper, the (L_1 Short) and (L_3 Short) Dryseal plug thread gages shall gage the same with relation to their respective notches within ½ turn.

Dryseal American (National) Standard Fuel Internal Straight Pipe Threads (NPSF) are gaged with the NPSF (L_1 Short) step-limit Dryseal plug thread gages (Table A10). Threads are within the allowable tolerance when the product reference point is on or between the limit notches. As depth gages without regard to limit notches, any of the (L_3) Dryseal plug thread gages may be used to check the full thread length of internal straight pipe threads.

Dryseal American (National) Standard Intermediate Internal Straight Pipe Threads (NPSI) are gaged with the NPSI (L_1) step-limit Dryseal plug thread gages (Table A12). Threads are within the allowable tolerance when the product reference point is on or between the limit notches. As depth gages without regard to limit notches, any of the (L_3) Dryseal plug thread gages may be used to check the full thread length of internal straight pipe threads.

Section III—Turns-Engagement Method of Gaging with Basic-Notch or Step-Limit Gages

The turns-engagement method of checking threaded product with plug thread and ring thread gages is a tactual check of the position of the gages in relation to the product. In checking by this method, either the basic-notch or the step-limit gages may be used. The gages are turned or screwed into or onto the threaded product and the turns to remove the gages are counted. This method compensates for gage chamfer and eliminates the variable of product chamfer.

Basic Turns Engagement of Ring Gages—The basic turns engagement of the (L_1) ring thread gages (Tables A1, A4, and A8) with Dryseal external taper pipe threads is the product of the (L_1) thread length of the ring gage used and the threads per inch, minus one turn to compensate for chamfer of the external threads and chamfer of the ring gages. (See accompanying tabulation of basic turns engagement.)

The basic turns engagement of the (L_2) ring thread gages (Tables A1, A5, and A9) with Dryseal external taper pipe threads is the product of the (L_2) thread length and the threads per inch, minus 1¼ turns to compensate for chamfer of the external threads and the chamfer and taper of the ring gages. (See accompanying tabulation of basic turns engagement.)

External Threads—Dryseal American (National) Standard External Taper Pipe Threads (NPTF) by the turns-engagement method may be gaged with any combination of (L_1) and (L_2) Dryseal ring thread gages (Tables A1, A4, A5, A8, and A9). Nominal turns engagement equals basic turns engagement. The tolerance is plus (small) 1 turn, minus (large) 1 turn. As a

Basic Turns Engagement[a]

SIZE	THREAD GAGE				
	L_1 rings		All L_2 rings	All L_1 plugs	All L_3 plugs
	Basic-notch, Table A1	Step-limit, Tables A4 and A8			
1/16–27	3.32	3.32	5.80	3.82	6.57
1/8 –27	3.86	3.36	5.87	3.86	6.61
1/4 –18	2.60	3.10	5.98	3.60	6.35
3/8 –18	3.32	3.32	6.09	3.82	6.57
1/2 –14	3.48	3.48	6.22	3.98	6.73
3/4 –14	3.75	3.75	6.39	4.25	7.00
1 –11½	3.60	3.60	6.60	4.10	6.85
1¼ –11½	3.83	3.83	6.88	4.33	7.08
1½ –11½	3.83	3.83	7.07	4.33	7.08
2 –11½	4.01	4.01	7.45	4.51	7.26
2½ –8	4.46	4.46	7.85	4.96	7.71
3 –8	5.13	5.13	8.35	5.63	8.38

[a] Derivation of nominal turns engagement and tolerance for the different thread types, NPTF, PTF—SAE Short, NPSF, and NPSI, is explained in accompanying text.

check on taper, the difference in turns engagement with the (L_1) and the (L_2) Dryseal ring thread gages shall be within ½ turn of the difference between the basic turns engagement of the ring gages.

Dryseal SAE Short External Taper Pipe Threads PTF—SAE Short, which are one thread shorter at the small end than standard full thread length, may be gaged by the turns-engagement method with any combination of (L_1) and (L_2) Dryseal ring thread gages (Tables A1, A4, A5, A8, and A9). Nominal turns engagement is one turn less than basic turns engagement. The tolerance is plus (small) 1 turn, minus (large) ½ turn. As a check on taper, the difference in turns engagement with the (L_1) and the (L_2) Dryseal ring thread gages shall be within ½ turn of the difference between the basic turns engagement of the ring gages.

Basic Turns Engagement of Plug Gages—The basic turns engagement of the (L_1) Dryseal plug thread gages (Tables A2, A6, A10, and A12) and Dryseal internal pipe threads is the product of the (L_1) thread length (Table 2) and the threads per inch, minus ½ turn to compensate for chamfer on plug gages. (See accompanying tabulation of basic turns engagement.)

The basic turns engagement of the (L_3) Dryseal plug thread gages (Tables A3, A7, and A11) with Dryseal internal pipe threads is the (L_1) thread length (Table 2) plus three threads, multiplied by the threads per inch, minus ¾ turn to compensate for chamfer and taper on plug gages. (See accompanying tabulation of basic turns engagement.)

Internal Threads—Dryseal American (National) Standard Internal Taper Pipe Threads (NPTF) are gaged with any combination of (L_1) and (L_3) Dryseal plug thread gages (Tables A2, A3, A6, A7, A10, A11, and A12). The nominal turns engagement equals basic turns engagement. The tolerance is plus (large) 1 turn, minus (small) 1 turn. As a check on taper, the difference in turns engagement of the (L_1) and the (L_3) Dryseal plug thread gages shall not be less than 2¼ turns nor more than 3¼ turns.

Dryseal SAE Short Internal Taper Pipe Thread PTF—SAE Short, which are one thread shorter at the large end than standard full thread length, are gaged with any combination of (L_1) and (L_3) Dryseal plug thread gages (Tables A2, A3, A6, A7, A10, A11, and A12). The nominal turns engagement is one turn less than basic turns engagement. The tolerance is plus (large) 1 turn, minus (small) ½ turn. As a check on taper, the difference in turns engagement of the (L_1) and the (L_3) Dryseal plug thread gages shall not be less than 2¼ turns nor more than 3¼ turns.

Dryseal American (National) Standard Fuel Internal Straight Pipe Threads (NPSF) are gaged with any of the (L_1) Dryseal plug thread gages (Tables A2, A6, A10, and A12). The nominal turns engagement is one turn less than basic turns engagement. The tolerance is plus (large) 1 turn, minus (small) ½ turn. As depth gages without regard to limit notches, any of the (L_3) Dryseal plug thread gages may be used to check the full thread length of internal straight pipe threads.

Dryseal American (National) Standard Intermediate Internal Straight Pipe Threads (NPSI) are gaged with any of the (L_1) Dryseal plug thread gages (Tables A2, A6, A10, and A12). The nominal turns engagement equals basic turns engagement. The tolerance is plus (large) 1 turn, minus (small) ½ turn. As depth gages without regard to limit notches, any of the (L_3) Dryseal plug thread gages may be used to check the full thread length of internal straight pipe threads.

(*Appendix B follows Table A12-1.*)

Dryseal American (National) Taper Pipe Thread (L_1 and L_2) Ring Gages

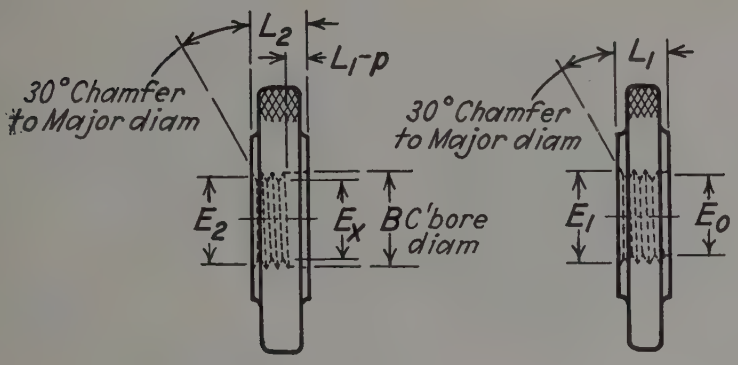


TABLE A1—*Basic Dimensions of Dryseal American (National) Taper Pipe Thread (L_1 and L_2) Basic-Notch Ring Gages*

SIZE	(L_2) BASIC-NOTCH FULL-RING GAGES							(L_1) BASIC-NOTCH THIN-RING GAGES				
	L_2	Pitch diameter, E_2	Minor diameter at large end[a]	Pitch diameter at L_1-p, E_x	Minor diameter at L_1-p[a]	L_1-p	B	L_1	Pitch diameter, E_1	Minor diameter at large end[a]	Pitch diameter, E_0	Minor diameter at small end[a]
1/16–27	0.26113	0.28750	0.27024	0.27886	0.26160	0.12296	3/8	0.1600	0.28118	0.26392	0.27118	0.25392
1/8 –27	0.26385	0.38000	0.36274	0.37244	0.35518	0.14296	15/32	0.1800	0.37476	0.35750	0.36351	0.34625
1/4 –18	0.40178	0.50250	0.47661	0.48642	0.46053	0.14444	19/32	0.2000	0.48989	0.46400	0.47739	0.45150
3/8 –18	0.40778	0.63750	0.61161	0.62354	0.59765	0.18444	23/32	0.2400	0.62701	0.60112	0.61201	0.58712
1/2 –14	0.53371	0.79179	0.75850	0.77396	0.74067	0.24857	7/8	0.3200	0.77843	0.74514	0.75843	0.72514
3/4 –14	0.54571	1.00179	0.96850	0.98440	0.95111	0.26757	1 3/32	0.3390	0.98887	0.95558	0.96768	0.93439
1 –11½	0.68278	1.25630	1.21577	1.23320	1.19267	0.31304	1 11/32	0.4000	1.23863	1.19810	1.21363	1.17310
1¼ –11½	0.70678	1.60130	1.56077	1.57794	1.53741	0.33304	1 11/16	0.4200	1.58338	1.54285	1.55713	1.51660
1½ –11½	0.72348	1.84130	1.80077	1.81690	1.77637	0.33304	1 15/16	0.4200	1.82234	1.78181	1.79609	1.75556
2 –11½	0.75652	2.31630	2.27577	2.29084	2.25031	0.34904	2½	0.4360	2.29627	2.25574	2.26902	2.22849
2½ –8	1.13750	2.79062	2.73237	2.75434	2.69609	0.55700	2 15/16	0.6820	2.76216	2.70391	2.71953	2.66128
3 –8	1.20000	3.41562	3.35737	3.38068	3.32243	0.64100	3 3/16	0.7660	3.38850	3.33025	3.34062	3.28237

[a] Minor diameter is based on crest minimum truncation of 0.20 p.

Marking—In addition to the regular markings, Dryseal American (National) Standard Taper Thread Thin-Ring Gages will be marked NPTF (L_1) and Full-Ring Gages will be marked NPTF (L_2)on the entering side of gage.

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at the minor diameter of ring gages and major diameter of plug gages shall be truncated 0.20p minimum to 0.25p maximum producing the minimum and maximum widths of flats specified in Table A1-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Thread Working Plug Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standards published in Commercial Standard CS8.

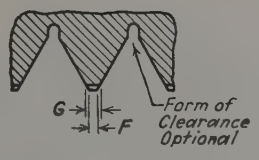


TABLE A1-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal American (National) Taper Pipe Thread (L_1) Plug Gages

Taper lock design, range ⅛ to 3 in., inclusive

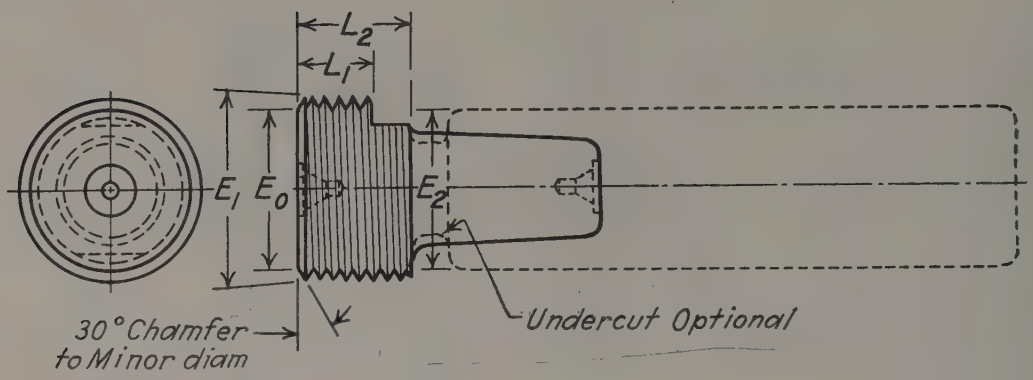


TABLE A2—*Basic Dimensions of Dryseal American (National) Taper Pipe Thread (L_1) Basic-Notch Plug Gages*

SIZE	L_1	L_2	SMALL END		GAGING NOTCH		LARGE END	
			Pitch diameter, E_0	Major diameter[a]	Pitch diameter, E_1	Major diameter[a]	Pitch diameter, E_2	Major diameter[a]
1/16–27	0.1600	0.26113	0.27118	0.28844	0.28118	0.29844	0.28750	0.30476
⅛ –27	0.1800	0.26385	0.36351	0.38077	0.37476	0.39202	0.38000	0.39726
¼ –18	0.2000	0.40178	0.47739	0.50328	0.48989	0.51578	0.50250	0.52839
⅜ –18	0.2400	0.40778	0.61201	0.63790	0.62701	0.65290	0.63750	0.66339
½ –14	0.3200	0.53371	0.75843	0.79170	0.77843	0.81170	0.79179	0.82506
¾ –14	0.3390	0.54571	0.96768	1.00095	0.98887	1.02214	1.00179	1.03506
1 –11½	0.4000	0.68278	1.21363	1.25416	1.23863	1.27916	1.25630	1.29683
1¼ –11½	0.4200	0.70678	1.55713	1.59766	1.58338	1.62391	1.60130	1.64183
1½ –11½	0.4200	0.72348	1.79609	1.83662	1.82234	1.86287	1.84130	1.88183
2 –11½	0.4360	0.75652	2.26902	2.30955	2.29627	2.33680	2.31630	2.35683
2½ –8	0.6820	1.13750	2.71953	2.77778	2.76216	2.82041	2.79062	2.84887
3 –8	0.7660	1.20000	3.34062	3.39887	3.38850	3.44675	3.41562	3.47387

[a] Major diameter is based upon crest minimum truncation of 0.20 p.

Marking—In addition to the regular markings, Dryseal American (National) Standard Taper Pipe Thread (L_1) Plug Gages will be marked NPTF (L_1).

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at the minor diameter of ring gages and major diameter of plug gages shall be truncated 0.20p minimum to 0.25p maximum producing the minimum and maximum widths of flats specified in Table A2-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Thread Working Plug Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standards published in Commercial Standard CS8.

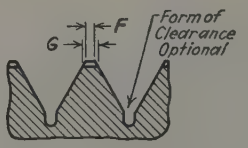


TABLE A2-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal American (National) Taper Pipe Thread (L_3) Length Plug Gages

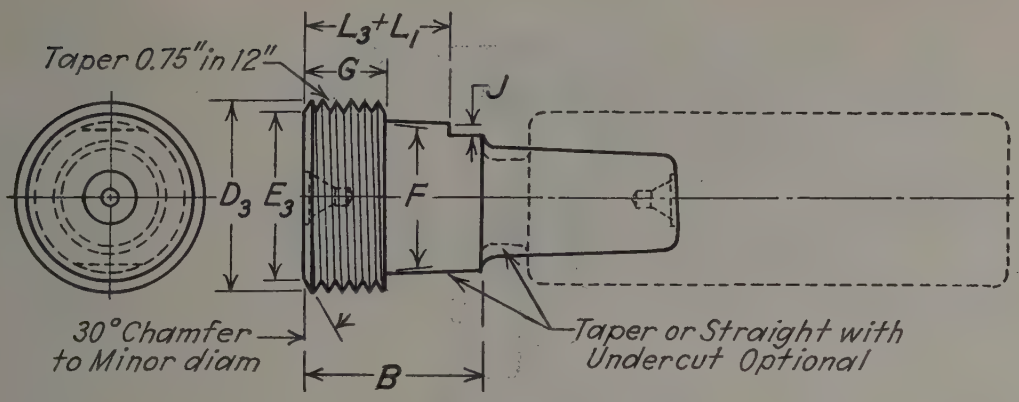


TABLE A3—*Basic Dimensions of Dryseal American (National) Taper Pipe Thread (L_3) Basic-Notch Length Plug Gages*

SIZE	SMALL END		RELIEF DIAMETER $[E_3 + (0.0625 \times 4p) -$ SHARP-V THD HGT $- 0.020$ TO 0.025 BELOW SHARP ROOT$] +0.005$ $F -0.000$	FOUR THREADS, G $(L_3 + p)$	STANDARD NOTCH PLUS 3 THREADS $(L_3 + L_1)$	BLANK LENGTH, B	NOTCH DEPTH, J $+0.005$ -0.000
	Pitch diameter, E_3	Major diameter,[a] D_3					
1/16–27	0.2642	0.2815	0.216	0.1482	0.2711	3/8	0.030
1/8 –27	0.3566	0.3738	0.309	0.1482	0.2911	13/32	0.030
1/4 –18	0.4670	0.4928	0.409	0.2222	0.3667	1/2	0.030
3/8 –18	0.6016	0.6275	0.542	0.2222	0.4067	9/16	0.030
1/2 –14	0.7451	0.7783	0.676	0.2857	0.5343	11/16	0.040
3/4 –14	0.9543	0.9876	0.886	0.2857	0.5533	23/32	0.040
1 –11½	1.1973	1.2379	1.118	0.3478	0.6609	7/8	0.050
1¼ –11½	1.5408	1.5814	1.462	0.3478	0.6809	7/8	0.050
1½ –11½	1.7798	1.8203	1.701	0.3478	0.6809	7/8	0.050
2 –11½	2.2527	2.2932	2.174	0.3478	0.6969	7/8	0.050
2½ –8	2.6961	2.7543	2.590	0.5000	1.0570	1½	0.050
3 –8	3.3172	3.3754	3.214	0.5000	1.1410	1½	0.050

[a] Major diameter is based upon crest minimum truncation of 0.20 p.

Marking—In addition to the regular markings, Dryseal American (National) Standard Taper Pipe Thread (L_3) Plug Gages will be marked NPTF (L_3).

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at major diameter shall be truncated $0.20p$ minimum to $0.25p$ maximum, producing the minimum and maximum widths of flat specified in Table A3-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Thread Working Plug Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standards published in Commercial Standard CS8.

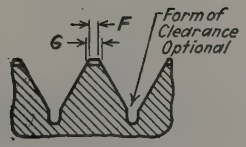


TABLE A3-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal American (National) Standard Taper Pipe Thread (L_1) Step-Limit Thin-Ring Gages

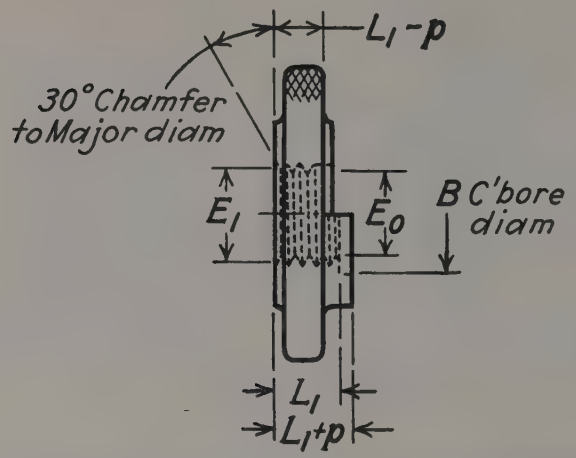


TABLE A4—*Basic Dimensions of Dryseal American (National) Standard Taper Pipe Thread (L_1) Step-Limit Thin-Ring Gages*

SIZE	(L_1) STEP-LIMIT THIN-RING GAGES							
	L_1	Max PD gaging step $L_1 - p$	Min PD gaging step $L_1 + p$	Pitch diameter, E_1	Minor diameter at large end[a]	Pitch diameter at small end c'bore, E_0	Minor diameter at small end c'bore[a]	B
1/16–27	0.1600	0.12296	0.19704	0.28118	0.26392	0.27118	0.25392	3/8
1/8 –27	0.16148	0.12444	0.19852	0.37360	0.35634	0.36351	0.34625	15/32
1/4 –18	0.22778	0.17222	0.28333	0.49163	0.46574	0.47739	0.45150	19/32
3/8 –18	0.2400	0.18444	0.29556	0.62701	0.60112	0.61201	0.58712	23/32
1/2 –14	0.3200	0.24857	0.39143	0.77843	0.74514	0.75843	0.72514	7/8
3/4 –14	0.3390	0.26757	0.41043	0.98887	0.95558	0.96768	0.93439	1 3/32
1 –11½	0.4000	0.31304	0.48696	1.23863	1.19810	1.21363	1.17310	1 11/32
1¼ –11½	0.4200	0.33304	0.50696	1.58338	1.54285	1.55713	1.51660	1 11/16
1½ –11½	0.4200	0.33304	0.50696	1.82234	1.78181	1.79609	1.75556	1 15/16
2 –11½	0.4360	0.34904	0.52296	2.29627	2.25574	2.26902	2.22849	2½
2½ –8	0.6820	0.55700	0.80700	2.76216	2.70391	2.71953	2.66128	2 15/16
3 –8	0.7660	0.64100	0.89100	3.38850	3.33025	3.34062	3.28237	3 5/16

[a] Minor diameter is based on crest minimum truncation of 0.20 p.

Marking—In addition to the regular markings, Dryseal American (National) Standard Taper Thread Ring Gages will be marked NPTF (L_1) on the entering side of gage.

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at the minor diameter shall be truncated 0.20p minimum to 0.25p maximum, producing the minimum and maximum widths of flat specified in Table A4-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Working Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standard published in Commercial Standard CS8.

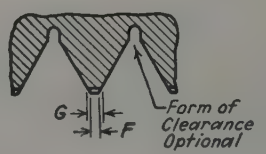


TABLE A4-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal American (National) Standard Taper Pipe Thread (L_2) Step-Limit Full-Ring Gages

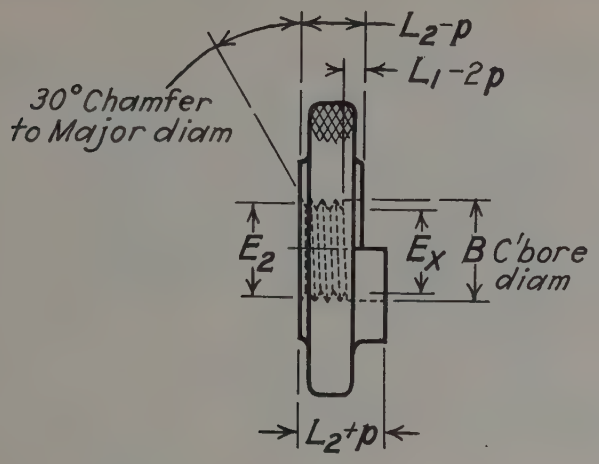
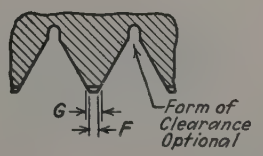


TABLE A5—*Basic Dimensions of Dryseal American (National) Standard Taper Pipe Thread (L_2) Step-Limit Full-Ring Gages*

SIZE	(L_2) STEP-LIMIT FULL-RING GAGES								
	L_2	Max PD gaging step $L_2 - p$	Min PD gaging step $L_2 + p$	Pitch diameter, E_2	Minor diameter at large end[a]	Pitch diameter at L_1 from min PD gaging step (E_x)	Minor diameter at small end c'bore[a]	$L_1 - 2p$	B
1/16–27	0.26113	0.22409	0.29817	0.28750	0.27024	0.27886	0.26160	0.08592	3/8
1/8 –27	0.26385	0.22681	0.30089	0.38000	0.36274	0.37244	0.35518	0.08740	15/32
1/4 –18	0.40178	0.34622	0.45734	0.50250	0.47661	0.48642	0.46053	0.11666	19/32
3/8 –18	0.40778	0.35222	0.46334	0.63750	0.61161	0.62354	0.59765	0.12888	23/32
1/2 –14	0.53371	0.46228	0.60514	0.79179	0.75850	0.77396	0.74067	0.17714	7/8
3/4 –14	0.54571	0.47428	0.61714	1.00179	0.96850	0.98440	0.95111	0.19614	1 3/32
1 –11½	0.68278	0.59582	0.76974	1.25630	1.21577	1.23320	1.19267	0.22608	1 11/32
1¼ –11½	0.70678	0.61982	0.79374	1.60130	1.56077	1.57794	1.53741	0.24608	1 11/16
1½ –11½	0.72348	0.63652	0.81044	1.84130	1.80077	1.81690	1.77637	0.24608	1 15/16
2 –11½	0.75652	0.66956	0.84348	2.31630	2.27577	2.29084	2.25031	0.26208	2 1/2
2½ –8	1.13750	1.01250	1.26250	2.79062	2.73237	2.75434	2.69609	0.43200	2 15/16
3 –8	1.20000	1.07500	1.32500	3.41562	3.35737	3.38068	3.32243	0.51600	3 9/16

[a] Minor diameter is based on crest minimum truncation of 0.20 p.



Marking—In addition to the regular markings, Dryseal American (National) Standard Taper Pipe Thread Ring Gages will be marked NPTF (L_2) on the entering side of gage.

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at the minor diameter shall be truncated $0.20p$ minimum to $0.25p$ maximum, producing the minimum and maximum widths of flat specified in Table A5-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Working Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standard published in Commercial Standard CS8.

TABLE A5-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal American (National) Standard Taper Pipe Thread (L_1) Step-Limit Plug Gages

Taper lock design, range ⅛ to 3 in., inclusive

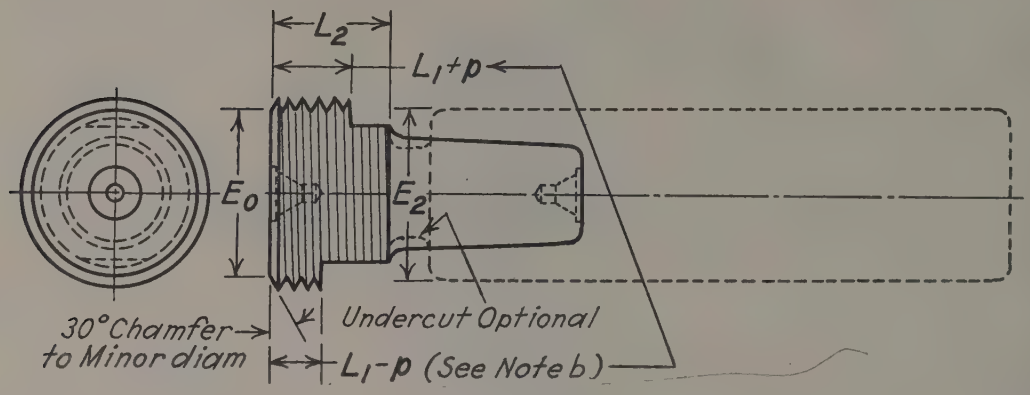


TABLE A6—*Basic Dimensions of Dryseal American (National) Standard Taper Pipe Thread (L_1) Step-Limit Plug Gages*

SIZE	L_1	L_2	SMALL END		MIN PD GAGING STEP		MAX PD GAGING STEP		LARGE END	
			Pitch diameter, E_0	Major diameter[a]	L_1-p	Pitch diameter	L_1+p	Pitch diameter	Pitch diameter, E_2	Major diameter[a]
1/16–27	0.1600	0.26113	0.27118	0.28844	0.12296	0.27887	0.19704	0.28350	0.28750	0.30476
⅛ –27	0.16148	0.26385	0.36351	0.38077	0.12444	0.37129	0.19852	0.37592	0.38000	0.39726
¼ –18	0.22778	0.40178	0.47739	0.50328	0.17222	0.48815	0.28333	0.49510	0.50250	0.52839
⅜ –18	0.2400	0.40778	0.61201	0.63790	0.18444	0.62354	0.29556	0.63048	0.63750	0.66339
½ –14	0.3200	0.53371	0.75843	0.79170	0.24857	0.77397	0.39143	0.78289	0.79179	0.82506
¾ –14	0.3390	0.54571	0.96768	1.00095	0.26757	0.98441	0.41043	0.99333	1.00179	1.03506
1 –11½	0.4000	0.68278	1.21363	1.25416	0.31304	1.23320	0.48696	1.24407	1.25630	1.29683
1¼ –11½	0.4200	0.70678	1.55713	1.59766	0.33304	1.57795	0.50696	1.58882	1.60130	1.64183
1½ –11½	0.4200	0.72348	1.79609	1.83662	0.33304	1.81691	0.50696	1.82778	1.84130	1.88183
2 –11½	0.4360	0.75652	2.26902	2.30955	0.34904	2.29084	0.52296	2.30171	2.31630	2.35683
2½ –8	0.6820	1.13750	2.71953	2.77778	0.55700	2.75435	0.80700	2.76997	2.79062	2.84887
3 –8	0.7660	1.20000	3.34062	3.39887	0.64100	3.38069	0.89100	3.39631	3.41562	3.47387

[a] Major diameter is based on crest minimum truncation of 0.20 p.
[b] Maximum and minimum pitch-diameter steps are gaging limits. Notch formulas on drawing apply to all sizes.

Marking—In addition to the regular markings, Dryseal American (National) Standard Taper Pipe Thread (L_1) Plug Gages will be marked NPTF (L_1).

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at major diameter shall be truncated 0.20p minimum to 0.25p maximum, producing the minimum and maximum widths of flat specified in Table A6-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Thread Working Plug Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standards published in Commercial Standard CS8.

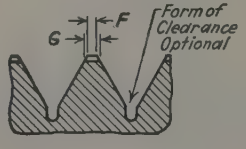


TABLE A6-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal American (National) Standard Taper Pipe Thread (L_3) Length Step-Limit Plug Gages

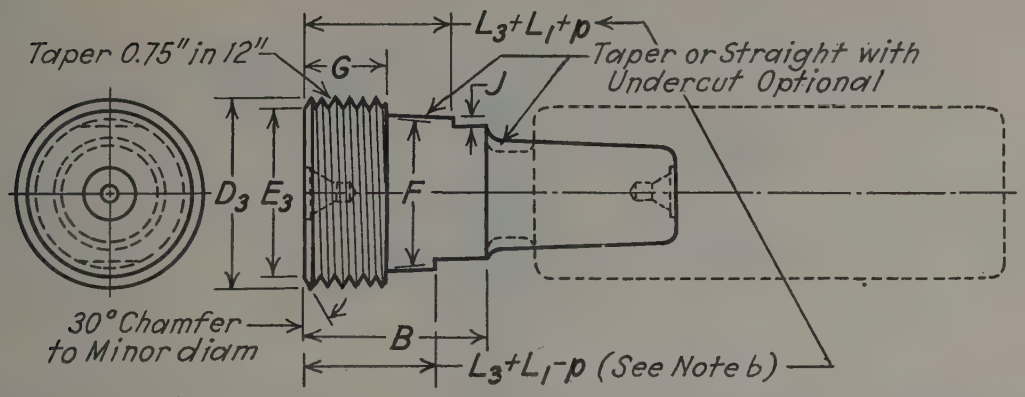


TABLE A7—*Basic Dimensions of Dryseal American (National) Standard Taper Pipe Thread (L_3) Length Step-Limit Plug Gages*

SIZE	SMALL END		RELIEF DIAMETER [$E_3 + (0.0625 \times 4p)$ − SHARP-V THD HGT − 0.020 TO 0.025 BELOW SHARP ROOT] +0.005 F −0.000	FOUR THREADS, G ($L_3 + p$)	MIN PD GAGING STEP PLUS 3 THREADS ($L_3 + L_1 - p$)	MAX PD GAGING STEP PLUS 3 THREADS ($L_3 + L_1 + p$)	BLANK LENGTH, B	NOTCH DEPTH, J +0.005 −0.000
	Pitch diameter, E_3	Major diameter,[a] D_3						
1/16–27	0.2642	0.2815	0.216	0.1482	0.2341	0.3082	3/8	0.030
1/8 –27	0.3566	0.3738	0.309	0.1482	0.2355	0.3097	13/32	0.030
1/4 –18	0.4670	0.4928	0.409	0.2222	0.3389	0.4500	1/2	0.030
3/8 –18	0.6016	0.6275	0.542	0.2222	0.3511	0.4622	9/16	0.030
1/2 –14	0.7451	0.7783	0.676	0.2857	0.4628	0.6057	11/16	0.040
3/4 –14	0.9543	0.9876	0.886	0.2857	0.4818	0.6247	23/32	0.040
1 –11½	1.1973	1.2379	1.118	0.3478	0.5739	0.7478	7/8	0.050
1¼ –11½	1.5408	1.5814	1.462	0.3478	0.5939	0.7678	7/8	0.050
1½ –11½	1.7798	1.8203	1.701	0.3478	0.5939	0.7678	7/8	0.050
2 –11½	2.2527	2.2932	2.174	0.3478	0.6099	0.7838	7/8	0.050
2½ –8	2.6961	2.7543	2.590	0.5000	0.9320	1.1820	1½	0.050
3 –8	3.3172	3.3754	3.214	0.5000	1.0160	1.2660	1½	0.050

[a] Major diameter is based upon crest minimum truncation of 0.20p.
[b] Maximum and minimum pitch-diameter steps are gaging limits. Notch formulas on drawing apply to all sizes.

Marking—In addition to the regular markings, Dryseal American (National) Standard Taper Pipe Thread (L_3) Plug Gages will be marked PTF (L_3).

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at major diameter shall be truncated 0.20p minimum to 0.25p maximum, producing the minimum and maximum widths of flat specified in Table A7-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Thread Working Plug Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standards published in Commercial Standard CS8.

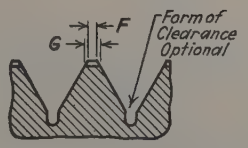


TABLE A7-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal SAE Short Taper Pipe Thread (L_1 Short) Step-Limit Thin-Ring Gages

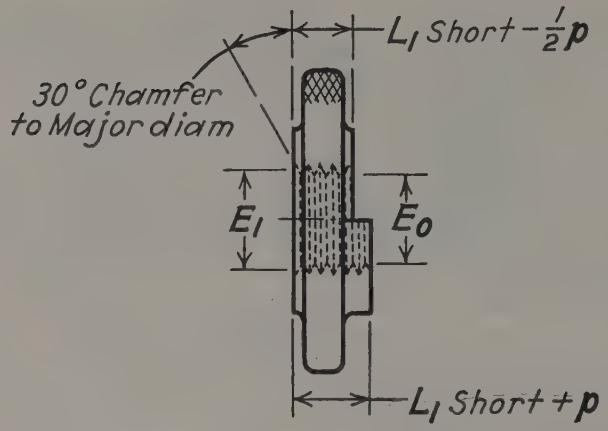


TABLE A8—*Basic Dimensions of Dryseal SAE Short Taper Pipe Thread (L_1 Short) Step-Limit Thin-Ring Gages*

SIZE	(L_1 SHORT) STEP-LIMIT THIN-RING GAGES						
	L_1 short	Max PD gaging step	Min PD gaging step	Pitch diameter, E_1	Minor diameter at large end[a]	Pitch diameter at min PD gaging step, E_0	Minor diameter at small end[a]
		L_1 short $-$ ½p	L_1 short $+$ p				
1/16–27	0.12296	0.10444	0.16000	0.28118	0.26392	0.27118	0.25392
1/8 –27	0.12446	0.10593	0.16148	0.37360	0.35634	0.36351	0.34625
1/4 –18	0.17224	0.14445	0.22778	0.49163	0.46574	0.47739	0.45150
3/8 –18	0.18444	0.15667	0.24000	0.62701	0.60112	0.61201	0.58712
1/2 –14	0.24857	0.21286	0.32000	0.77843	0.74514	0.75843	0.72514
3/4 –14	0.26757	0.23186	0.33900	0.98887	0.95558	0.96768	0.93439
1 –11½	0.31304	0.26957	0.40000	1.23863	1.19810	1.21363	1.17310
1¼ –11½	0.33304	0.28957	0.42000	1.58338	1.54285	1.55713	1.51660
1½ –11½	0.33304	0.28957	0.42000	1.82234	1.78181	1.79609	1.75556
2 –11½	0.34904	0.30557	0.43600	2.29627	2.25574	2.26902	2.22849
2½ –8	0.55700	0.49450	0.68200	2.76216	2.70391	2.71953	2.66128
3 –8	0.64100	0.57850	0.76600	3.38850	3.33025	3.34062	3.28237

[a] Minor diameter is based on crest minimum truncation of 0.20p.

Marking—In addition to the regular markings, Dryseal SAE Short Taper Pipe Thread Ring Gages will be marked PTF—SAE Short (L_1 Short) on the entering side of gage.

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at the minor diameter shall be truncated 0.20p minimum to 0.25p maximum, producing the minimum and maximum widths of flat specified in Table A8-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Working Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standard published in Commercial Standard CS8.

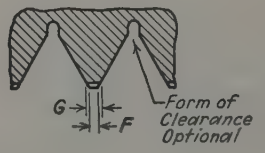


TABLE A8-1—*Thread Flats*

THREADS PER IN.	*F*	*G*
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal SAE Short Taper Pipe Thread (L_2 Short) Step-Limit Full-Ring Gages

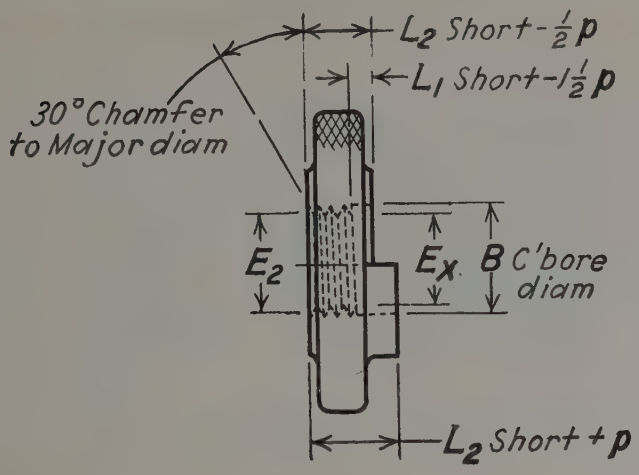


TABLE A9—*Basic Dimensions of Dryseal SAE Short Taper Pipe Thread (L_2 Short) Step-Limit Full-Ring Gages*

SIZE	(L_2 SHORT) STEP-LIMIT FULL-RING GAGES								
	L_2 short	Max PD gaging step	Min PD gaging step	Pitch diameter, E_2	Minor diameter at large end[a]	Pitch diameter at L_1 short $-1\frac{1}{2}p$ from min PD gaging step, E_x	Minor diameter at small end c'bore[a]	L_1 short $-1\frac{1}{2}p$	B
		L_2 short $-\frac{1}{2}p$	L_2 short $+p$						
1/16–27	0.2241	0.20557	0.26113	0.28750	0.27024	0.27886	0.26160	0.06740	3/8
1/8 –27	0.2268	0.20829	0.26385	0.38000	0.36274	0.37244	0.35518	0.06890	15/32
1/4 –18	0.3462	0.31845	0.40178	0.50250	0.47661	0.48642	0.46053	0.08891	19/32
3/8 –18	0.3522	0.32445	0.40778	0.63750	0.61161	0.62354	0.59765	0.10111	23/32
1/2 –14	0.4623	0.42657	0.53371	0.79179	0.75850	0.77396	0.74067	0.14143	7/8
3/4 –14	0.4743	0.43857	0.54571	1.00179	0.96850	0.98440	0.95111	0.16043	1 3/32
1 –11½	0.5958	0.55235	0.68278	1.25630	1.21577	1.23320	1.19267	0.18260	1 11/32
1¼ –11½	0.6198	0.57635	0.70678	1.60130	1.56077	1.57794	1.53741	0.20260	1 11/16
1½ –11½	0.6365	0.59305	0.72348	1.84130	1.80077	1.81690	1.77637	0.20260	1 15/16
2 –11½	0.6695	0.62609	0.75652	2.31630	2.27577	2.29084	2.25031	0.21860	2½
2½ –8	1.0125	0.95000	1.13750	2.79062	2.73237	2.75434	2.69609	0.36950	2 15/16
3 –8	1.0750	1.01250	1.20000	3.41562	3.35737	3.38068	3.32243	0.45350	3 9/16

[a] Minor diameter is based on crest minimum truncation of 0.20 p.

Marking—In addition to the regular markings, Dryseal SAE Short Taper Pipe Thread Ring Gages will be marked PTF—SAE Short (L_2 Short) on the entering side of gage.

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at the minor diameter shall be truncated 0.20p minimum to 0.25p maximum, producing the minimum and maximum widths of flat specified in Table A9-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Working Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standard published in Commercial Standard CS8.

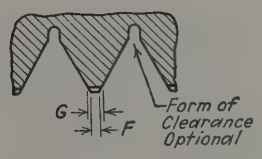


TABLE A9-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal SAE Short Taper Pipe Thread and Dryseal American (National) Standard Fuel Internal Straight Pipe Thread (L_1 Short) Step-Limit Plug Gages

Taper lock design, range ⅛ to 2 in., inclusive

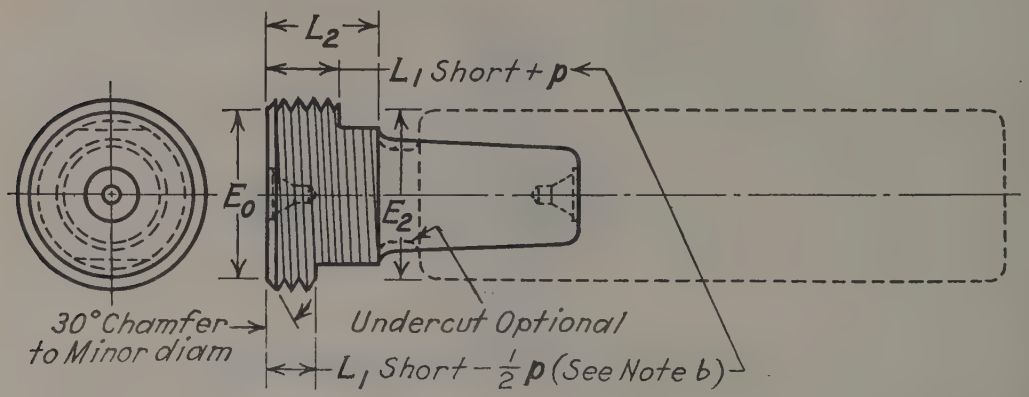


TABLE A10—*Basic Dimensions of Dryseal SAE Short Taper Pipe Thread and Dryseal American (National) Standard Fuel Internal Straight Pipe Thread (L_1 Short) Step-Limit Plug Gages*

SIZE	L_1 SHORT	L_2	SMALL END		MIN PD GAGING STEP		MAX PD GAGING STEP		LARGE END	
			Pitch diameter, E_0	Major diameter[a]	L_1 short − ½ p	Pitch diameter	L_1 short + p	Pitch diameter	Pitch diameter, E_2	Major diameter[a]
1/16–27	0.12296	0.26113	0.27118	0.28844	0.10444	0.27771	0.16000	0.28118	0.28750	0.30476
⅛ –27	0.12444	0.26385	0.36351	0.38077	0.10592	0.37013	0.16148	0.37360	0.38000	0.39726
¼ –18	0.17222	0.40178	0.47739	0.50328	0.14444	0.48642	0.22778	0.49163	0.50250	0.52839
⅜ –18	0.18444	0.40778	0.61201	0.63790	0.15667	0.62180	0.24000	0.62701	0.63750	0.66339
½ –14	0.24857	0.53371	0.75843	0.79170	0.21286	0.77174	0.32000	0.77843	0.79179	0.82506
¾ –14	0.26757	0.54571	0.96768	1.00095	0.23186	0.98218	0.33900	0.98887	1.00179	1.03506
1 –11½	0.31304	0.68278	1.21363	1.25416	0.26957	1.23048	0.40000	1.23863	1.25630	1.29683
1¼ –11½[c]	0.33304	0.70678	1.55713	1.59766	0.28957	1.57523	0.42000	1.58338	1.60130	1.64183
1½ –11½[c]	0.33304	0.72348	1.79609	1.83662	0.28957	1.81419	0.42000	1.82234	1.84130	1.88183
2 –11½[c]	0.34904	0.75652	2.26902	2.30955	0.30557	2.28812	0.43600	2.29627	2.31630	2.35683
2½ –8[c]	0.55700	1.13750	2.71953	2.77778	0.49450	2.75044	0.68200	2.76216	2.79062	2.84887
3 –8[c]	0.64100	1.20000	3.34062	3.39887	0.57850	3.37678	0.76600	3.38850	3.41562	3.47387

[a] Major diameter is based on crest minimum truncation of 0.20 p.
[b] Maximum and minimum pitch-diameter steps are gaging limits. Notch formulas on drawing apply to all sizes.
[c] For reference only above 1-11½ NPSF.

Marking—In addition to the regular markings, Dryseal SAE Short Taper Pipe Thread L_1 Short Plug Gages will be marked PTF—SAE Short (L_1 Short). Dryseal American (National) Standard Fuel Internal Straight Pipe Thread Taper Plug Gages will be marked NPSF (L_1 Short).

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at major diameter shall be truncated 0.20p minimum to 0.25p maximum, producing the minimum and maximum widths of flat specified in Table A10-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Thread Working Plug Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standards published in Commercial Standard CS8.

TABLE A10-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal SAE Short Taper Pipe Thread (L_3 Short) Length Step-Limit Plug Gages

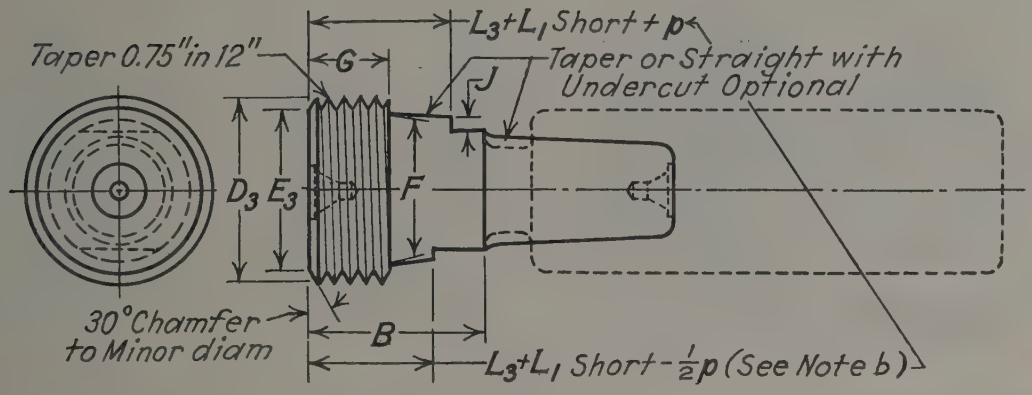


TABLE A11—*Basic Dimensions of Dryseal SAE Short Taper Pipe Thread (L_3 Short) Length Step-Limit Plug Gages*

SIZE	SMALL END		RELIEF DIAMETER [$E_3 + (0.0625 \times 4p)$ — SHARP-V THD HGT — 0.020 TO 0.025 BELOW SHARP ROOT] + 0.005 F —0.000	FOUR THREADS, G ($L_3 + p$)	MIN PD GAGING STEP PLUS 3 THREADS (L_3 + L_1 SHORT − ½p)	MAX PD GAGING STEP PLUS 3 THREADS (L_3 + L_1 SHORT + p)	BLANK LENGTH, B	NOTCH DEPTH, J +0.005 −0.000
	Pitch diameter, E_3	Major diameter,[a] D_3						
1/16–27	0.2642	0.2815	0.216	0.1482	0.2156	0.2711	3/8	0.030
1/8 –27	0.3566	0.3738	0.309	0.1482	0.2170	0.2726	13/32	0.030
1/4 –18	0.4670	0.4928	0.409	0.2222	0.3112	0.3945	1/2	0.030
3/8 –18	0.6016	0.6275	0.542	0.2222	0.3233	0.4067	9/16	0.030
1/2 –14	0.7451	0.7783	0.676	0.2857	0.4271	0.5343	11/16	0.040
3/4 –14	0.9543	0.9876	0.886	0.2857	0.4462	0.5533	23/32	0.040
1 –11½	1.1973	1.2379	1.118	0.3478	0.5304	0.6609	7/8	0.050
1¼ –11½	1.5408	1.5814	1.462	0.3478	0.5504	0.6809	7/8	0.050
1½ –11½	1.7798	1.8203	1.701	0.3478	0.5504	0.6809	7/8	0.050
2 –11½	2.2527	2.2932	2.174	0.3478	0.5664	0.6969	7/8	0.050
2½ –8	2.6961	2.7543	2.590	0.5000	0.8695	1.0570	1½	0.050
3 –8	3.3172	3.3754	3.214	0.5000	0.9535	1.1410	1½	0.050

[a] Major diameter is based upon crest minimum truncation of 0.20 p.
[b] Maximum and minimum pitch-diameter steps are gaging limits. Notch formulas on drawing apply to all sizes.

Marking—In addition to the regular markings, Dryseal SAE Short Taper Pipe Thread (L_3) Plug Gages will be marked PTF—SAE Short (L_3 Short).

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at major diameter shall be truncated 0.20p minimum to 0.25p maximum, producing the minimum and maximum widths of flat specified in Table A11-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Thread Working Plug Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standards published in Commercial Standard CS8.

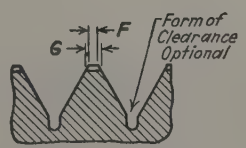


TABLE A11-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Dryseal American (National) Intermediate Internal Straight Pipe Thread (L_1) Step-Limit Plug Gages

Taper lock design, range ⅛ to 1 in., inclusive

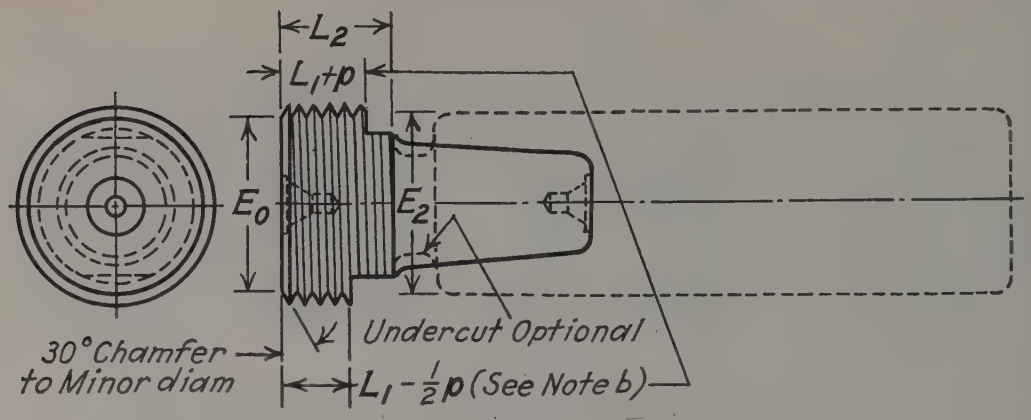
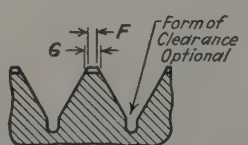


TABLE A12—*Basic Dimensions of Dryseal American (National) Intermediate Internal Straight Pipe Thread (L_1) Step-Limit Plug Gages*

SIZE	L_1	L_2	SMALL END		MIN PD GAGING STEP		MAX PD GAGING STEP		LARGE END	
			Pitch diameter, E_0	Major diameter[a]	$L_1 - \frac{1}{2}p$	Pitch diameter	$L_1 + p$	Pitch diameter	Pitch diameter, E_2	Major diameter[a]
1/16–27	0.1600	0.26113	0.27118	0.28844	0.14148	0.28003	0.19704	0.28350	0.28750	0.30476
⅛ –27	0.16148	0.26385	0.36351	0.38077	0.14296	0.37245	0.19852	0.37592	0.38000	0.39726
¼ –18	0.22778	0.40178	0.47739	0.50328	0.20000	0.48989	0.28333	0.49510	0.50250	0.52839
⅜ –18	0.2400	0.40778	0.61201	0.63790	0.21223	0.62527	0.29556	0.63048	0.63750	0.66339
½ –14	0.3200	0.53371	0.75843	0.79170	0.28429	0.77619	0.39143	0.78289	0.79179	0.82506
¾ –14	0.3390	0.54571	0.96768	1.00095	0.30329	0.98663	0.41043	0.99333	1.00179	1.03506
1 –11½	0.4000	0.68278	1.21363	1.25416	0.35653	1.23592	0.48696	1.24407	1.25630	1.29683
1¼ –11½[c]	0.1200	0.70678	1.55713	1.59766	0.37653	1.58066	0.50696	1.58882	1.60130	1.64183
1½ –11½[c]	0.1200	0.72348	1.79609	1.83662	0.37653	1.81962	0.50696	1.82778	1.84130	1.88183
2 –11½[c]	0.4360	0.75652	2.26902	2.30955	0.39253	2.29355	0.52296	2.30171	2.31630	2.35683
2½ –8[c]	0.6820	1.13750	2.71953	2.77778	0.61950	2.75825	0.80700	2.76997	2.79062	2.84887
3 –8[c]	0.7660	1.20000	3.34062	3.39887	0.70350	3.38459	0.89100	3.39631	3.41562	3.47387

[a] Major diameter is based on crest minimum truncation of 0.20 p.
[b] Maximum and minimum pitch-diameter steps are gaging limits. Notch formulas on drawing apply to all sizes.
[c] For reference only.



Marking—In addition to the regular markings, Dryseal SAE Intermediate Internal Straight Pipe Thread Taper Plug Gages will be marked NPSI (L_1).

Thread Form—The threads in all particulars excepting truncation shall conform to American (National) Standard Taper Pipe Thread practice. Crests of threads at major diameter shall be truncated 0.20p minimum to 0.25p maximum, producing the minimum and maximum widths of flat specified in Table A12-1.

All other thread dimensions shall be within tolerances specified for the American (National) Standard Pipe Thread Working Plug Gages (ASA B2.1-1945). Other gage details shall conform to American Gage Design Standards published in Commercial Standard CS8.

TABLE A12-1—*Thread Flats*

THREADS PER IN.	F	G
27	0.0086	0.0107
18	0.0128	0.0160
14	0.0165	0.0206
11½	0.0201	0.0251
8	0.0289	0.0361

Appendix B

External Cut Thread Blanks, Drilled Hole Sizes, Hole Depths, Full Thread Lengths, Tap and Chaser Tooth Form, and Taps—While production taps will usually be purchased to specification, occasions may arise requiring adaptation of taps, dies, or chasers at hand.

American (National) Standard Taper Taps, Dies, or Chasers (NPT) may be adapted for producing the Dryseal American (National) Standard Taper Pipe Threads (NPTF) by truncating the outside diameter of taps and the inside diameter of dies or chasers the amount necessary to obtain flats shown in Table B3 for producing the limits on the product specified in Table 1. The pitch diameter of taps and dies or chasers so modified will remain standard. American (National) Standard Coupling Straight Pipe Taps (NPSC) used for tapping the American (National) Standard Coupling Straight Pipe Thread (NPSC), with the exception of one size only, may be adapted for tapping the Dryseal American (National) Intermediate Straight Pipe Thread (NPSI) by truncating the outside diameter the amount necessary to obtain flats shown in Table B3 for producing the limits on the product shown in Table 1. The exception is the ¼–18 in. size which has a minimum pitch diameter under that required. With the exception of one size only, taps designed to other standards cannot be adapted for tapping the Dryseal American (National) Fuel Straight Pipe Thread (NPSF). The exception is the ⅛–27 in. American (National) Standard Grease Fitting Tap (NPSG) which, if made in conformity with Tap Manufacturers' Standards of 1939 to 1941 issue, may be used without change for tapping of the ⅛–27 in. Dryseal American (National) Fuel Straight Pipe Thread (NPSF).

Dryseal American (National) Standard External Taper Pipe Thread Blanks, Cut Threads

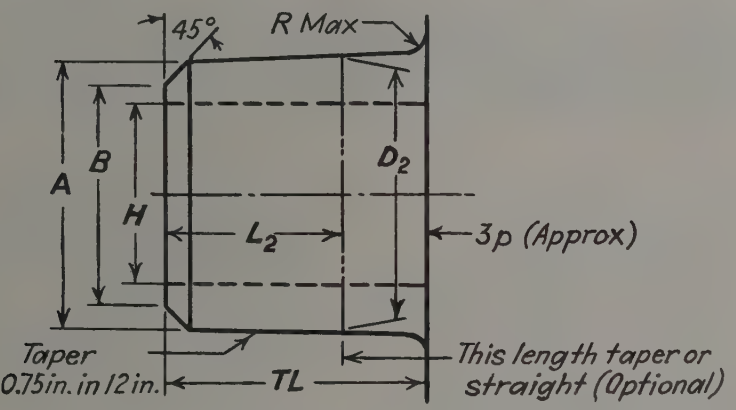


TABLE B1—*Dimensions of Dryseal American (National) Standard External Taper Pipe Thread Blanks, Cut Threads*

SIZE	OUTSIDE DIAMETER AT L_2 LENGTH FROM SMALL END (BASIC THD ONE TURN LARGE WITH MAX TRUNC)	OUTSIDE DIAMETER AT SMALL END (BASIC THD TWO TURNS LARGE WITH MAX TRUNC)	CHAMFER DIAMETER (MINOR DIAMETER AT SMALL END)	MINIMUM LENGTH FROM SMALL END TO SHOULDER, L_1 + (3 p APPROX)	CORNER RADIUS	RECOMMENDED HOLE SIZE[a]
	D_2 +0.003 −0.000	A +0.003 −0.000	B +0.000 −1/64	TL	R, max	H
1/16–27	0.315	0.301	15/64	3/8	1/32	1/8
1/8 –27	0.407	0.393	21/64	3/8	1/32	3/16
1/4 –18	0.546	0.523	27/64	9/16	1/16	9/32
3/8 –18	0.681	0.658	9/16	9/16	1/16	13/32
1/2 –14	0.850	0.820	11/16	3/4	5/64	9/16
3/4 –14	1.060	1.029	29/32	3/4	5/64	23/32
1 –11½	1.327	1.289	1 1/8	15/16	3/32	15/16
1¼ –11½	1.672	1.633	1 15/32	31/32	3/32	1 1/4
1½ –11½	1.912	1.872	1 11/16	1	3/32	1 15/32
2 –11½	2.387	2.345	2 5/32	1 1/32	3/32	1 15/16
2½ –8	2.893	2.829	2 19/32	1 33/64	1/8	2 5/16
3 –8	3.518	3.450	3 7/32	1 37/64	1/8	2 29/32

[a] The hole sizes recommended represent a desirable maximum, strength of wall being considered. However, as considerations other than wall strength frequently control the hole size in specific applications, the recommendations should not be construed as a requirement of this Standard.

Pipe-Thread Drilled Hole Sizes for Dryseal American (National) Standard Internal Pipe Thread

TABLE B2—*Pipe-Thread Drilled Hole Sizes*

SIZE	STRAIGHT PIPE THREAD						TAPER PIPE THREAD								COUNTERSINK
	Fuel (NPSF)		Intermediate (NPSI)		Min desired length of full thd	Hole depth for plug end tap, Tables B6 and B7	NPTF Commercial[a] (not reamed)				NPTF[b] (taper reamed)		Min desired length of full thd	Hole depth for standard tap, Table B4	90° x diameter + 1/64 − 0.000
	Min minor diameter[c]	Drilled hole size, +0.003 −0.001	Min minor diameter[c]	Drilled hole size, +0.003 −0.001			Min minor diameter 2 thds small from large end	Drilled hole size, +0.003 −0.001	Min minor diameter 4 thds small from large end	Drilled hole size, +0.003 −0.001	Min desired minor diameter at small end	Drilled hole size, +0.003 −0.001			
1/16–27	0.2482	0.2500	0.2505	0.2500	5/16	15/32	0.2480	0.2460	0.2434	0.2420	0.2356	0.2344	5/16	9/16	5/16
1/8 –27	0.3406	0.3437	0.3429	0.3437	5/16	15/32	0.3403	0.3390	0.3357	0.3320	0.3279	0.3281	5/16	9/16	13/32
1/4 –18	0.4422	0.4440	0.4457	0.4440	15/32	23/32	0.4417	0.4375	0.4348	0.4290	0.4241	0.4219	15/32	13/16	35/64
3/8 –18	0.5776	0.5781	0.5811	0.5781	1/2	23/32	0.5771	0.5781	0.5702	0.5700	0.5587	0.5625	1/2	13/16	43/64
1/2 –14	0.7133	0.7187	0.7180	0.7187	21/32	15/16	0.7127	0.7031	0.7038	0.6960	0.6883	0.6875	21/32	1 1/16	27/32
3/4 –14	0.9238	—	0.9283	—	21/32	15/16	0.9232	0.9219	0.9143	0.9062	0.8976	0.8906	21/32	1 1/16	1 3/64
1 –11½	1.1600	—	1.1655	—	25/32	1 5/32	1.1593	1.1562	1.1484	1.1406	1.1290	1.1250	25/32	1 1/4	1 5/16
1¼ –11½	—	—	—	—	—	—	1.5041	1.5000	1.4932	1.4844	1.4725	1.4687	13/16	1 5/16	1 21/32
1½ –11½	—	—	—	—	—	—	1.7430	1.7344	1.7321	1.7198	1.7115	1.7031	13/16	1 5/16	1 29/32
2 –11½	—	—	—	—	—	—	2.2170	2.2187	2.2061	2.2031	2.1844	2.1875	13/16	1 5/16	2 3/8
2½ –8	—	—	—	—	—	—	2.6488	2.6406	2.6336	2.6250	2.5983	2.5937	1 1/4	1 27/32	2 29/32
3 –8	—	—	—	—	—	—	3.2751	3.2656	3.2595	3.2500	3.2194	3.2187	1 11/32	1 29/32	3 17/32

[a] NPTF commercial (not reamed) drilled hole sizes are recommended for taper tapping without reaming. Minimum minor diameter two threads small from large end and closest drilled hole sizes are recommended only for low pressure use. Minimum minor diameter four threads small from large end and closest drilled hole sizes are recommended for all pressures. Thread lengths so produced are designated "Effective Thread" on drawings.

[b] NPTF (taper reamed) drilled hole sizes are recommended for taper reaming before tapping. They also are used without taper reaming by taper drilling or allowing the tap to act as a reamer. Thread lengths so produced are designated "Full or Complete Thread" on drawings.

[c] Minimum minor diameter for internal straight pipe threads is based upon minimum pitch diameter and minimum truncation and will vary with the pitch diameter.

NPSG (for oil and grease cup) is Dryseal American (National) Standard Pipe Thread Form—use NPSF tap drill sizes.

The drilled hole sizes given above for Dryseal straight and taper internal pipe threads are the diameters produced by drills which are closest to the minimum minor diameters as shown in Table B2.

They represent the diameters of the holes which would be cut with a twist drill correctly ground when drilling a material without tearing or flow of metal. This is approximately the condition obtained when a correctly sharpened twist drill is cutting a hole in SAE 1112 or 1113 steel, or SAE 72 brass. When Dryseal taps are used, these holes produce an acceptable pipe thread with the required thread height.

When flat drills are used, the width of the cutting edge may have to be adjusted to produce a hole of the required diameter.

When hard metals and other similar materials are to be drilled and tapped, it may be found necessary to use a drill of slightly smaller diameter to produce a hole of a size that will make it possible for the tap to cut an acceptable pipe thread with the required thread height.

When soft metals and other similar materials are to be drilled and tapped, it may be found necessary to use a drill of slightly larger diameter to produce a hole of a size that will allow for a flow of the metal or material without loading the tap or tearing the material and make it possible for the tap to produce an acceptable pipe thread with the required thread height.

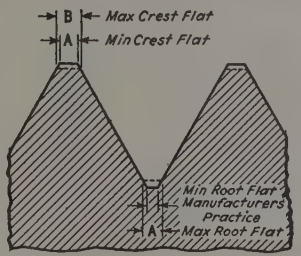
It should be understood that this table of drilled hole sizes is intended to help only the occasional user of drills in the application of this Standard. When internal pipe threads are produced in larger quantities in a particular type of material and with specially designed machinery, it may be found to be more advantageous to use a drilled hole size not given in the table, even one requiring a nonstandard diameter drill size.

Dryseal Pipe Thread Chasers and Taps for Dryseal American (National) Standard Pipe Thread

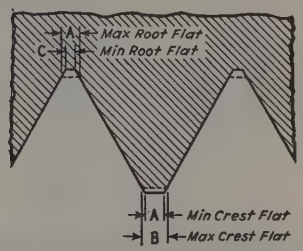
TABLE B3—*Widths of Flats*

THREADS PER IN.	*A*	*B*	*C*
27	0.004	0.005	0.002
18	0.005	0.006	0.003
14	0.005	0.006	0.003
11½	0.006	0.008	0.004
8	0.008	0.010	0.006[a]

[a] There is reason to doubt the correctness of the 8-pitch flat widths because of the volume of metal to be displaced.



ENLARGED SECTION OF TAP TEETH



ENLARGED SECTION OF CHASER TEETH

TABLE B4—*Dryseal Taper Pipe Taps for Dryseal American (National) Standard Internal Taper Pipe Thread, Ground Thread Limits*

PTF SIZE	GAGE[a] MEASURE		MAJOR-DIAMETER FLAT		MINOR-DIAMETER FLAT[b]
	Min	Max	Min	Max	Max
1/16–27	0.250	0.375	0.004	0.005	0.004
1/8 –27	0.250	0.375	0.004	0.005	0.004
1/4 –18	0.397	0.521	0.005	0.006	0.005
3/8 –18	0.392	0.516	0.005	0.006	0.005
1/2 –14	0.517	0.641	0.005	0.006	0.005
3/4 –14	0.503	0.627	0.005	0.006	0.005
1 –11½	0.584	0.772	0.006	0.008	0.006
1¼ –11½	0.592	0.780	0.006	0.008	0.006
1½ –11½	0.605	0.793	0.006	0.008	0.006
2 –11½	0.573	0.761	0.006	0.008	0.006
2½ –8	0.831	1.019	0.008	0.010	0.008
3 –8	0.831	1.019	0.008	0.010	0.008

[a] Distance small end of tap projects beyond face of American (National) Standard Thin-Ring Gage.
[b] Minor diameter as specified or sharper.

Chamfer—2 to 3 threads.

Lead Tolerance—A maximum lead error of plus or minus 0.0005 in. in 1 in. of thread is permitted.

Angle Tolerance—Error in half angle of plus or minus 30 min is permitted.

Taper Tolerance—A maximum taper error of plus or minus 1/32 in. per ft is permitted.

Marking—In addition to regular markings, Dryseal American (National) Standard Taper Taps will be marked NPTF.

TABLE B5—*Dryseal Taper Pipe Taps for Dryseal SAE Short Internal Taper Pipe Thread, Ground Thread Limits*

PTF—SAE SHORT SIZE	GAGE[a] MEASURE		MAJOR-DIAMETER FLAT		MINOR-DIAMETER FLAT[b]
	Min (6p)	Max (7p)	Min	Max	Max
1/16–27	0.222	0.259	0.004	0.005	0.004
1/8 –27	0.222	0.259	0.004	0.005	0.004
1/4 –18	0.333	0.389	0.005	0.006	0.005
3/8 –18	0.333	0.389	0.005	0.006	0.005
1/2 –14	0.429	0.500	0.005	0.006	0.005
3/4 –14	0.429	0.500	0.005	0.006	0.005

[a] Distance small end of tap projects beyond face of American (National) Standard Thin-Ring Gage.
[b] Minor diameter as specified or sharper.

Chamfer—1½ to 2 threads.

Marking—In addition to regular markings, Dryseal SAE Short Taper Taps will be marked PTF—SAE Short.

Tolerances—Same as for Dryseal American (National) Standard Taper Taps.

(*Tables continued on next page.*)

TABLE B6—*Dryseal Straight Pipe Taps for Dryseal American (National) Fuel Internal Straight Pipe Thread, Ground Thread Limits*

NPSF SIZE	PITCH DIAMETER			MAJOR-DIAMETER FLAT[a]		MINOR-DIAMETER FLAT[b]	MAJOR DIAMETER		
	Basic	Min	Max	Min	Max	Max	Basic	Min	Max
1/16–27	0.2812	0.2767	0.2777	0.004	0.005	0.004	0.3108	0.3008	0.3018
1/8 –27	0.3748	0.3691	0.3701	0.004	0.005	0.004	0.4044	0.3932	0.3942
1/4 –18	0.4899	0.4854	0.4864	0.005	0.006	0.005	0.5343	0.5239	0.5249
3/8 –18	0.6270	0.6208	0.6218	0.005	0.006	0.005	0.6714	0.6593	0.6608
1/2 –14	0.7784	0.7707	0.7717	0.005	0.006	0.005	0.8356	0.8230	0.8240
3/4 –14	0.9889	0.9807	0.9822	0.005	0.006	0.005	1.0460	1.0335	1.0345
1 –11½	1.2386	1.2294	1.2305	0.006	0.008	0.006	1.3082	1.2933	1.2943

[a] For reference only. Major-diameter flats specified may be slightly larger or smaller with extreme combinations of pitch diameter, major diameter, and half angle.
[b] Minor diameter as specified or sharper.

Chamfer—Plug end 3 to 5 threads, intermediate end 2 to 3 threads, bottom end 1½ to 2 threads.

Lead Tolerance—A maximum lead error of plus or minus 0.0005 in. in 1 in. of thread is permitted.

Angle Tolerance—Error in half angle of plus or minus 30 min permitted.

Marking—In addition to regular markings, Dryseal American (National) Fuel Straight Pipe Taps will be marked NPSF.

Maximum Major Diameter equals minimum pitch diameter plus sharp-V thread height minus twice tool crest minimum truncation.

Minimum Major Diameter equals maximum major diameter minus tolerance.

Maximum Pitch Diameter equals the E_1 pitch diameter at large end of internal thread (Table 2) minus (small) 1½ threads taper.

Minimum Pitch Diameter equals maximum pitch diameter minus tolerance.

TABLE B7—*Dryseal Straight Pipe Taps for Dryseal American (National) Intermediate Internal Straight Pipe Thread, Ground Thread Limits*

NPSI SIZE	PITCH DIAMETER			MAJOR-DIAMETER FLAT[a]		MINOR-DIAMETER FLAT[b]	MAJOR DIAMETER		
	Basic	Min	Max	Min	Max	Max	Basic	Min	Max
1/16–27	0.2812	0.2790	0.2800	0.004	0.005	0.004	0.3108	0.3031	0.3041
1/8 –27	0.3748	0.3714	0.3724	0.004	0.005	0.004	0.4044	0.3955	0.3965
1/4 –18	0.4899	0.4889	0.4899	0.005	0.006	0.005	0.5343	0.5274	0.5284
3/8 –18	0.6270	0.6243	0.6253	0.005	0.006	0.005	0.6714	0.6628	0.6638
1/2 –14	0.7784	0.7752	0.7762	0.005	0.006	0.005	0.8356	0.8275	0.8285
3/4 –14	0.9889	0.9857	0.9867	0.005	0.006	0.005	1.0460	1.0380	1.0390
1 –11½	1.2386	1.2348	1.2359	0.006	0.008	0.006	1.3082	1.2987	1.2997

[a] For reference only. Major-diameter flats specified may be slightly larger or smaller with extreme combinations of pitch diameter, major diameter, and half angle.
[b] Minor diameter as specified or sharper.

Chamfer—Plug end 3 to 5 threads, intermediate end 2 to 3 threads, bottom end 1½ to 2 threads.

Lead Tolerance—A maximum lead error of plus or minus 0.0005 in. in 1 in. of thread is permitted.

Angle Tolerance—Error in half angle of plus or minus 30 min permitted.

Marking—In addition to regular markings, American (National) Intermediate Straight Pipe Taps will be marked NPSI.

Maximum Major Diameter equals minimum pitch diameter plus sharp-V thread height minus twice tool crest minimum truncation.

Minimum Major Diameter equals maximum major diameter minus tolerance.

Maximum Pitch Diameter equals the E_1 pitch diameter at large end of internal thread (Table 2) minus (small) ½ thread taper.

Minimum Pitch Diameter equals maximum pitch diameter minus tolerance.

Wrench-Head Screw and Bolt Heads, Nuts, and Wrench Openings

SAE Standard

Report of Screw Threads Division approved June 1911 and last revised January 1942. This SAE Standard conforms to American Standard Wrench-Head Bolts and Nuts and Wrench Openings, ASA B18.2-1941.

[The original standard for regular automobile bolts and nuts was adopted by the Mechanical Branch of the Association of Licensed Automobile Manufacturers in conjunction with the standard series of ALAM screw threads, in April 1906. In June 1911, this was adopted by SAE, which took over several ALAM standards at that time, and was continued until the first American Standard B18 for screw and bolt heads and nuts was adopted in 1927. At this time, the SAE Standard was separated into two

(Text continued at top of next page.)

TABLE 1—*Dimensions of Regular Bolt Heads, Unfinished, Square, and Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS, MIN		HEIGHT		
		Max (basic)		Min	Sq	Hex	Nom	Max	Min
1/4	0.2500	3/8	0.3750	0.362	0.498	0.413	11/64	0.188	0.156
5/16	0.3125	1/2	0.5000	0.484	0.665	0.552	13/64	0.220	0.186
3/8	0.3750	9/16	0.5625	0.544	0.747	0.620	1/4	0.268	0.232
7/16	0.4375	5/8	0.6250	0.603	0.828	0.687	19/64	0.316	0.278
1/2	0.5000	3/4	0.7500	0.725	0.995	0.826	21/64	0.348	0.308
9/16	0.5625	7/8	0.8750	0.847	1.163	0.966	3/8	0.396	0.354
5/8	0.6250	15/16	0.9375	0.906	1.244	1.033	27/64	0.444	0.400
3/4	0.7500	1 1/8	1.1250	1.088	1.494	1.240	1/2	0.524	0.476
7/8	0.8750	1 5/16	1.3125	1.269	1.742	1.447	19/32	0.620	0.568
1	1.0000	1 1/2	1.5000	1.450	1.991	1.653	21/32	0.684	0.628
1 1/8	1.1250	1 11/16	1.6875	1.631	2.239	1.859	3/4	0.780	0.720
1 1/4	1.2500	1 7/8	1.8750	1.812	2.489	2.066	27/32	0.876	0.812
1 3/8	1.3750	2 1/16	2.0625	1.994	2.738	2.273	29/32	0.940	0.872
1 1/2	1.5000	2 1/4	2.2500	2.175	2.986	2.480	1	1.036	0.964
1 5/8	1.6250	2 7/16	2.4375	2.356	3.235	2.686	1 3/32	1.132	1.056
1 3/4	1.7500	2 5/8	2.6250	2.538	3.485	2.893	1 5/32	1.196	1.116
1 7/8	1.8750	2 13/16	2.8125	2.719	3.733	3.100	1 1/4	1.292	1.208
2	2.0000	3	3.0000	2.900	3.982	3.306	1 11/32	1.388	1.300
2 1/4	2.2500	3 3/8	3.3750	3.262	4.479	3.719	1 1/2	1.548	1.452
2 1/2	2.5000	3 3/4	3.7500	3.625	4.977	4.133	1 21/32	1.708	1.604
2 3/4	2.7500	4 1/8	4.1250	3.988	5.476	4.546	1 13/16	1.889	1.777
3	3.0000	4 1/2	4.5000	4.350	5.973	4.959	2	2.060	1.940

Regular bolt heads are for general use.

Unfinished bolt heads are not finished on any surface.

Taper of the bolt heads (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Top of bolt heads shall be flat and chamfered; angle of chamfer with top surface shall be 25 deg for square and 30 deg for hexagon; diameter of top circle shall be the maximum width across flats, within a tolerance of minus 15%.

Bearing surface shall be at right angles to the axis of the body of the bolt within a tolerance of 3 deg for 1-in. bolts or smaller and 2 deg for bolts larger than 1 in. and concentric with the axis of the body within a tolerance of 3% of maximum width across flats.

Maximum radius under head of bolts for sizes 1/4 to 1/2 in. shall be 1/32; for sizes 9/16 to 1 in. shall be 1/16; for sizes 1 1/8 to 2 in. shall be 1/8; for sizes 2 1/4 to 3 in. shall be 3/16.

(*Continued from top of preceding page.*)

Standards, one for screw threads and the other for screw and bolt heads and nuts.

The tables and data in the Standard are for screw and bolt heads and nuts commonly used in automotive products. They conform with the tables and data of ASA B18.2-1941, except that SAE Table 20a is ASA Appendix Table 2, and SAE Table 20b is ASA Appendix Table 3.]

Wrench Openings—The minimum wrench openings have been made to provide a positive clearance between maximum nut and

(*Text continued at top of next page.*)

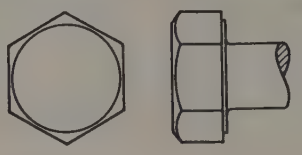


TABLE 2—*Dimensions of Regular Bolt Heads, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	HEIGHT		
		Max (basic)		Min	Min	Nom	Max	Min
1/4	0.2500	3/8	0.3750	0.362	0.413	5/32	0.172	0.140
5/16	0.3125	1/2	0.5000	0.484	0.552	3/16	0.205	0.171
3/8	0.3750	9/16	0.5625	0.544	0.620	15/64	0.252	0.216
7/16	0.4375	5/8	0.6250	0.603	0.687	9/32	0.300	0.262
1/2	0.5000	3/4	0.7500	0.725	0.826	19/64	0.317	0.277
9/16	0.5625	7/8	0.8750	0.847	0.966	11/32	0.365	0.323
5/8	0.6250	15/16	0.9375	0.906	1.033	25/64	0.413	0.369
3/4	0.7500	1 1/8	1.1250	1.088	1.240	15/32	0.493	0.445
7/8	0.8750	1 5/16	1.3125	1.269	1.447	9/16	0.589	0.536
1	1.0000	1 1/2	1.5000	1.450	1.653	19/32	0.622	0.566
1 1/8	1.1250	1 11/16	1.6875	1.631	1.859	11/16	0.718	0.658
1 1/4	1.2500	1 7/8	1.8750	1.812	2.066	25/32	0.813	0.749
1 3/8	1.3750	2 1/16	2.0625	1.994	2.273	27/32	0.878	0.810
1 1/2	1.5000	2 1/4	2.2500	2.175	2.480	15/16	0.974	0.902
1 5/8	1.6250	2 7/16	2.4375	2.356	2.686	1 1/32	1.069	0.993
1 3/4	1.7500	2 5/8	2.6250	2.538	2.893	1 3/32	1.134	1.054
1 7/8	1.8750	2 13/16	2.8125	2.719	3.100	1 3/16	1.230	1.146
2	2.0000	3	3.0000	2.900	3.306	1 7/32	1.263	1.175
2 1/4	2.2500	3 3/8	3.3750	3.262	3.719	1 3/8	1.423	1.327
2 1/2	2.5000	3 3/4	3.7500	3.625	4.133	1 17/32	1.583	1.479
2 3/4	2.7500	4 1/8	4.1250	3.988	4.546	1 11/16	1.744	1.632
3	3.0000	4 1/2	4.5000	4.350	4.959	1 7/8	1.935	1.815

Regular bolt heads are for general use.

Semifinished bolt heads are finished under head.

Taper of bolt heads (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Top of bolt heads shall be flat and chamfered; angle of chamfer with top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats, within a tolerance of minus 15%.

Bearing surface shall be washer faced. The thickness of the washer face shall be approximately 1/64 in. included in the head height and diameter of the washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the body of the bolt within a tolerance of 2 deg for 1-in. bolts or smaller and 1 deg for bolts larger than 1 in. and concentric with the axis of the body within a tolerance of 3% of the maximum width across flats.

Maximum radius under head of bolt for sizes 1/4 to 1/2 in. shall be 1/32; for sizes 9/16 to 1 in. shall be 1/16; for sizes 1 1/8 to 2 in. shall be 1/8; for sizes 2 1/4 to 3 in. shall be 3/16.

Finished regular bolt heads when specified shall be made to the dimensions and tolerances given for the semifinished product, degree and character of finish to be specified in each case.

(*Continued from top of preceding page.*)

minimum wrench opening. The plus tolerance allowed has been made as great as is possible without deformation of the corners of bolt heads or nuts under extreme conditions.

Nomenclature—The following definitions will apply to the terms as used in this Standard:

Unfinished—Unfinished bolt heads or nuts are not machined or treated on any surface except in the threads.

Semifinished—Semifinished bolt heads or nuts are machined or otherwise formed or treated on the bearing surface so as to provide for nuts either a washer face or a circular bearing surface formed by chamfering the edges, and for bolt heads a washer face.

Finished—Finished bolt heads and nuts are the same as semifinished except that the surfaces other than the bearing surface have been so treated as to provide a special appearance. The finish desired on all nonbearing surfaces of finished bolt heads and nuts should be specified by the purchaser.

Washer Face—The washer face is a circular boss turned or otherwise produced on the bearing surface of a bolt head or nut to relieve the corners.

A circular bearing surface can also be produced by chamfering the corners of the nut.

Height of Head—The height of head is the overall distance from the top to the bearing surface and includes the thickness of the washer face where provided.

Thickness of Nut—The thickness of nut is the overall distance from the top to the bearing surface and includes the thickness of the washer face where provided.

Taper of Bolt Head or Nut—The taper of a bolt head or nut is the angle between a side and the axis.

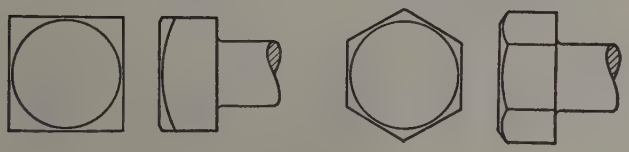


TABLE 3 –*Dimensions of Heavy Bolt Heads, Unfinished, Square, and Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS, MIN		HEIGHT		
		Max (basic)		Min	Sq	Hex	Nom	Max	Min
1/2	0.5000	7/8	0.8750	0.850	1.167	0.969	7/16	0.458	0.418
9/16	0.5625	15/16	0.9375	0.909	1.249	1.037	15/32	0.490	0.448
5/8	0.6250	1 1/16	1.0625	1.031	1.416	1.175	17/32	0.553	0.509
3/4	0.7500	1 1/4	1.2500	1.212	1.665	1.383	5/8	0.649	0.601
7/8	0.8750	1 7/16	1.4375	1.394	1.914	1.589	23/32	0.745	0.693
1	1.0000	1 5/8	1.6250	1.575	2.162	1.796	13/16	0.840	0.784
1 1/8	1.1250	1 13/16	1.8125	1.756	2.411	2.002	29/32	0.936	0.876
1 1/4	1.2500	2	2.0000	1.938	2.661	2.209	1	1.032	0.968
1 3/8	1.3750	2 3/16	2.1875	2.119	2.909	2.416	1 3/32	1.128	1.060
1 1/2	1.5000	2 3/8	2.3750	2.300	3.158	2.622	1 3/16	1.224	1.152
1 5/8	1.6250	2 9/16	2.5625	2.481	3.406	2.828	1 9/32	1.319	1.243
1 3/4	1.7500	2 3/4	2.7500	2.662	3.655	3.036	1 3/8	1.415	1.335
1 7/8	1.8750	2 15/16	2.9375	2.844	3.905	3.242	1 15/32	1.511	1.427
2	2.0000	3 1/8	3.1250	3.025	4.153	3.449	1 9/16	1.606	1.518
2 1/4	2.2500	3 1/2	3.5000	3.388	4.652	3.862	1 3/4	1.798	1.702
2 1/2	2.5000	3 7/8	3.8750	3.750	5.149	4.275	1 15/16	1.990	1.886
2 3/4	2.7500	4 1/4	4.2500	4.112	5.646	4.688	2 1/8	2.181	2.069
3	3.0000	4 5/8	4.6250	4.475	6.144	5.102	2 5/16	2.373	2.252

Heavy bolt heads are for use where greater bearing surface is necessary.

Unfinished bolt heads are not finished on any surface.

Taper of bolt heads (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Top of bolt heads shall be flat and chamfered; angle of chamfer with the top surface shall be 25 deg for square and 30 deg for hexagon; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be at right angles to the axis of the body of the bolt within a tolerance of 3 deg for 1-in. bolts or smaller and 2 deg for bolts larger than 1 in. and concentric with the axis of the body within a tolerance of 3% of the maximum width across flats.

Maximum radius under head of bolts for 1/2 in. size shall be 1/32; for sizes 9/16 to 1 in. shall be 1/16; for sizes 1 1/8 to 2 in. shall be 1/8; for sizes 2 1/4 to 3 in. shall be 3/16.

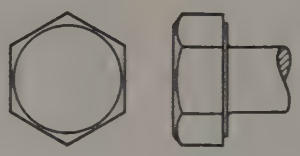


TABLE 4—*Dimensions of Heavy Bolt Heads, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	HEIGHT		
		Max (basic)		Min	Min	Nom	Max	Min
1/2	0.5000	7/8	0.8750	0.850	0.969	13/32	0.426	0.386
9/16	0.5625	15/16	0.9375	0.909	1.037	7/16	0.459	0.417
5/8	0.6250	1 1/16	1.0625	1.031	1.175	1/2	0.522	0.478
3/4	0.7500	1 1/4	1.2500	1.212	1.383	19/32	0.618	0.570
7/8	0.8750	1 7/16	1.4375	1.394	1.589	11/16	0.714	0.662
1	1.0000	1 5/8	1.6250	1.575	1.796	3/4	0.778	0.722
1 1/8	1.1250	1 13/16	1.8125	1.756	2.002	27/32	0.874	0.814
1 1/4	1.2500	2	2.0000	1.938	2.209	15/16	0.970	0.906
1 3/8	1.3750	2 3/16	2.1875	2.119	2.416	1 1/32	1.065	0.997
1 1/2	1.5000	2 3/8	2.3750	2.300	2.622	1 1/8	1.161	1.089
1 5/8	1.6250	2 9/16	2.5625	2.481	2.828	1 7/32	1.257	1.181
1 3/4	1.7500	2 3/4	2.7500	2.662	3.035	1 5/16	1.352	1.272
1 7/8	1.8750	2 15/16	2.9375	2.844	3.242	1 13/32	1.448	1.364
2	2.0000	3 1/8	3.1250	3.025	3.449	1 7/16	1.482	1.394
2 1/4	2.2500	3 1/2	3.5000	3.388	3.862	1 5/8	1.673	1.577
2 1/2	2.5000	3 7/8	3.8750	3.750	4.275	1 13/16	1.864	1.760
2 3/4	2.7500	4 1/4	4.2500	4.112	4.688	2	2.056	1.944
3	3.0000	4 5/8	4.6250	4.475	5.102	2 3/16	2.248	2.128

Heavy bolt heads are for use where greater bearing surface is necessary.

Semifinished bolt heads are finished under head.

Taper of bolt heads (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Top of bolt heads shall be flat and chamfered; angle of chamfer with the top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced. The thickness of the washer face shall be approximately 1/64 in. included in the head height, and diameter of the washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the body of the bolt within a tolerance of 2 deg for 1-in. bolts or smaller and 1 deg for bolts larger than 1 in. and concentric with the axis of the body within a tolerance of 3% of the maximum width across flats.

Maximum radius under head of bolts for 1/2 in. size shall be 1/32; for sizes 9/16 to 1 in. shall be 1/16; for sizes 1 1/8 to 2 in. shall be 1/8; for sizes 2 1/4 to 3 in. shall be 3/16.

Finished heavy bolt heads when specified shall be made to the dimensions and tolerances given for the semifinished product, degree and character of finish to be specified in each case.

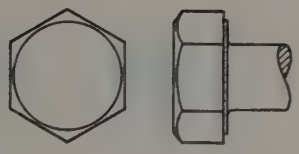


TABLE 5—*Dimensions of Capscrew Heads, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	HEIGHT		
		Max (basic)		Min	Min	Nom	Max	Min
1/4	0.2500	7/16	0.4375	0.428	0.488	3/16	0.194	0.181
5/16	0.3125	1/2	0.5000	0.489	0.557	15/64	0.242	0.227
3/8	0.3750	9/16	0.5625	0.551	0.628	9/32	0.289	0.273
7/16	0.4375	5/8	0.6250	0.612	0.698	21/64	0.338	0.319
1/2	0.5000	3/4	0.7500	0.736	0.840	3/8	0.386	0.364
9/16	0.5625	13/16	0.8125	0.798	0.910	27/64	0.433	0.410
5/8	0.6250	7/8	0.8750	0.860	0.980	15/32	0.481	0.456
3/4	0.7500	1	1.0000	0.983	1.121	9/16	0.577	0.548
7/8	0.8750	1 1/8	1.1250	1.106	1.261	21/32	0.672	0.640
1	1.0000	1 5/16	1.3125	1.292	1.473	3/4	0.768	0.732
1 1/8	1.1250	1 1/2	1.5000	1.477	1.684	27/32	0.864	0.824
1 1/4	1.2500	1 11/16	1.6875	1.663	1.896	15/16	0.959	0.916

Full finished capscrews have all surfaces, including body and all surfaces of the head, machined or otherwise treated to provide a surface equivalent in appearance. For special applications the degree of the finish may be specified between the user and the manufacturer.

Capscrews when threaded with either coarse or fine threads shall have a length of thread equal to twice the diameter plus 1/4 in. The minimum thread length is measured from the end of the bolt to the last complete thread. Screws too short to allow the formula length thread shall be threaded as close to the head as practicable.

Top of head shall be flat and chamfered; angle of chamfer with top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced. Thickness of washer face shall be approximately 1/64 in., included in the head height, and diameter of washer face shall be the maximum width across flats within a tolerance of plus or minus 5%.

Bearing surface shall be at right angles to the axis of the body within a tolerance of 2 deg for 1-in. screws or smaller and 1 deg for screws larger than 1 in. and concentric with the axis of the body within a tolerance of 3% of the maximum width across flats.

Radius of fillet under head for sizes 1/4 to 5/8 in. shall be 0.01 to 1/64 in.; for sizes 1 1/16 to 1 in. shall be 1/64 to 1/32 in.; for sizes 1 1/16 to 1 1/4 in. shall be 1/32 to 3/64 in.

TABLE 6—*Dimensions of Setscrew Heads, Square*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	HEIGHT			DIAMETER OF NECK	
		Max (basic)		Min	Min	Nom	Max	Min	Max	Min
1/4	0.2500	1/4	0.2500	0.241	0.331	3/16	0.196	0.178	0.185	0.170
5/16	0.3125	5/16	0.3125	0.302	0.415	15/64	0.245	0.224	0.240	0.225
3/8	0.3750	3/8	0.3750	0.362	0.497	9/32	0.293	0.270	0.294	0.279
7/16	0.4375	7/16	0.4375	0.423	0.581	21/64	0.341	0.315	0.345	0.330
1/2	0.5000	1/2	0.5000	0.484	0.665	3/8	0.389	0.361	0.400	0.385
9/16	0.5625	9/16	0.5625	0.545	0.748	27/64	0.437	0.407	0.454	0.439
5/8	0.6250	5/8	0.6250	0.606	0.833	15/32	0.485	0.452	0.507	0.492
3/4	0.7500	3/4	0.7500	0.729	1.001	9/16	0.582	0.544	0.620	0.605
7/8	0.8750	7/8	0.8750	0.852	1.170	21/32	0.678	0.635	0.731	0.716
1	1.0000	1	1.0000	0.974	1.337	3/4	0.774	0.726	0.838	0.823
1 1/8	1.1250	1 1/8	1.1250	1.096	1.505	27/32	0.870	0.817	0.939	0.914
1 1/4	1.2500	1 1/4	1.2500	1.219	1.674	15/16	0.966	0.908	1.064	1.039
1 3/8	1.3750	1 3/8	1.3750	1.342	1.843	1 1/32	1.063	1.000	1.159	1.134
1 1/2	1.5000	1 1/2	1.5000	1.464	2.010	1 1/8	1.159	1.091	1.284	1.259

Width of neck under head shall not be over two times the pitch of the thread.

The under surface of the head shall be beveled not more than 40 deg.

Top or crown of head shall be rounded to a radius of two and a half times the major diameter of the thread.

TABLE 7—*Dimensions of Regular Nuts and Regular Jam Nuts, Unfinished, Square, and Hexagon (Jam Nuts, Hexagon Only)*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS, MIN		THICKNESS, REGULAR NUTS			THICKNESS, REGULAR JAM NUTS		
		Max (basic)		Min	Sq	Hex	Nom	Max	Min	Nom	Max	Min
1/4	0.2500	7/16	0.4375	0.425	0.584	0.484	7/32	0.235	0.203	5/32	0.172	0.140
5/16	0.3125	9/16	0.5625	0.547	0.751	0.624	17/64	0.283	0.249	3/16	0.204	0.170
3/8	0.3750	5/8	0.6250	0.606	0.832	0.691	21/64	0.346	0.310	7/32	0.237	0.201
7/16	0.4375	3/4	0.7500	0.728	1.000	0.830	3/8	0.394	0.356	1/4	0.269	0.231
1/2	0.5000	13/16	0.8125	0.788	1.082	0.898	7/16	0.458	0.418	5/16	0.332	0.292
9/16	0.5625	7/8	0.8750	0.847	1.163	0.966	1/2	0.521	0.479	11/32	0.365	0.323
5/8	0.6250	1	1.0000	0.969	1.330	1.104	35/64	0.569	0.525	3/8	0.397	0.353
3/4	0.7500	1 1/8	1.1250	1.088	1.494	1.240	21/32	0.680	0.632	7/16	0.462	0.414
7/8	0.8750	1 5/16	1.3125	1.269	1.742	1.447	49/64	0.792	0.740	1/2	0.526	0.474
1	1.0000	1 1/2	1.5000	1.450	1.991	1.653	7/8	0.903	0.847	9/16	0.590	0.534
1 1/8	1.1250	1 11/16	1.6875	1.631	2.239	1.859	1	1.030	0.970	5/8	0.655	0.595
1 1/4	1.2500	1 7/8	1.8750	1.812	2.489	2.066	1 3/32	1.126	1.062	3/4	0.782	0.718
1 3/8	1.3750	2 1/16	2.0625	1.994	2.738	2.273	1 13/64	1.237	1.169	13/16	0.846	0.778
1 1/2	1.5000	2 1/4	2.2500	2.175	2.986	2.480	1 5/16	1.348	1.276	7/8	0.911	0.839
1 5/8	1.6250	2 7/16	2.4375	2.356	3.235	2.686	1 27/64	1.460	1.384	15/16	0.976	0.900
1 3/4	1.7500	2 5/8	2.6250	2.538	3.485	2.893	1 17/32	1.571	1.491	1	1.040	0.960
1 7/8	1.8750	2 13/16	2.8125	2.719	3.733	3.100	1 41/64	1.683	1.599	1 1/16	1.104	1.020
2	2.0000	3	3.0000	2.900	3.982	3.306	1 3/4	1.794	1.706	1 1/8	1.169	1.081
2 1/4	2.2500	3 3/8	3.3750	3.262	4.479	3.719	1 31/32	2.017	1.921	1 1/4	1.298	1.202
2 1/2	2.5000	3 3/4	3.7500	3.625	4.977	4.133	2 3/16	2.240	2.136	1 1/2	1.552	1.448
2 3/4	2.7500	4 1/8	4.1250	3.988	5.476	4.546	2 13/32	2.462	2.350	1 5/8	1.681	1.569
3	3.0000	4 1/2	4.5000	4.350	5.973	4.959	2 5/8	2.685	2.565	1 3/4	1.810	1.690

Regular nuts are for general use.

Unfinished nuts are not finished on any surface but are threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered or (except in jam nuts) washer crowned. For flat and chamfered nuts the angle of chamfer with the top surface shall be 25 deg for square and 30 deg for hexagon; diameter of the top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 3 deg for 1-in. nuts or smaller and 2 deg for nuts larger than 1 in.

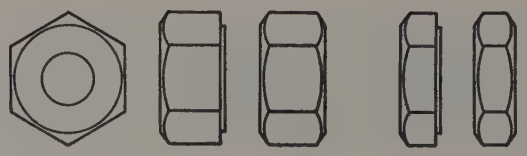


TABLE 8—*Dimensions of Regular Nuts and Regular Jam Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS, REGULAR NUTS			THICKNESS, REGULAR JAM NUTS		
		Max (basic)		Min	Min	Nom	Max	Min	Nom	Max	Min
1/4	0.2500	7/16	0.4375	0.425	0.485	13/64	0.219	0.187	9/64	0.157	0.125
5/16	0.3125	9/16	0.5625	0.547	0.624	1/4	0.267	0.233	11/64	0.189	0.155
3/8	0.3750	5/8	0.6250	0.606	0.691	5/16	0.330	0.294	13/64	0.221	0.185
7/16	0.4375	3/4	0.7500	0.728	0.830	23/64	0.378	0.340	15/64	0.253	0.215
1/2	0.5000	13/16	0.8125	0.788	0.898	27/64	0.442	0.402	19/64	0.317	0.277
9/16	0.5625	7/8	0.8750	0.847	0.966	31/64	0.505	0.463	21/64	0.349	0.307
5/8	0.6250	1	1.0000	0.969	1.104	17/32	0.553	0.509	23/64	0.381	0.337
3/4	0.7500	1 1/8	1.1250	1.088	1.240	41/64	0.665	0.617	27/64	0.446	0.398
7/8	0.8750	1 5/16	1.3125	1.269	1.447	3/4	0.776	0.724	31/64	0.510	0.458
1	1.0000	1 1/2	1.5000	1.450	1.653	55/64	0.887	0.831	35/64	0.575	0.519
1 1/8	1.1250	1 11/16	1.6875	1.631	1.859	31/32	0.999	0.939	39/64	0.639	0.579
1 1/4	1.2500	1 7/8	1.8750	1.812	2.066	1 1/16	1.094	1.030	23/32	0.751	0.687
1 3/8	1.3750	2 1/16	2.0625	1.994	2.273	1 11/64	1.206	1.138	25/32	0.815	0.747
1 1/2	1.5000	2 1/4	2.2500	2.175	2.480	1 9/32	1.317	1.245	27/32	0.880	0.808
1 5/8	1.6250	2 7/16	2.4375	2.356	2.686	1 25/64	1.429	1.353	29/32	0.944	0.868
1 3/4	1.7500	2 5/8	2.6250	2.538	2.893	1 1/2	1.540	1.460	31/32	1.009	0.929
1 7/8	1.8750	2 13/16	2.8125	2.719	3.100	1 39/64	1.651	1.567	1 1/32	1.073	0.989
2	2.0000	3	3.0000	2.900	3.306	1 23/32	1.763	1.675	1 3/32	1.138	1.050
2 1/4	2.2500	3 3/8	3.3750	3.262	3.719	1 59/64	1.970	1.874	1 13/64	1.251	1.155
2 1/2	2.5000	3 3/4	3.7500	3.625	4.133	2 9/64	2.193	2.089	1 29/64	1.505	1.401
2 3/4	2.7500	4 1/8	4.1250	3.988	4.546	2 23/64	2.415	2.303	1 37/64	1.634	1.522
3	3.0000	4 1/2	4.5000	4.350	4.959	2 37/64	2.638	2.518	1 45/64	1.763	1.643

Regular nuts are for general use.

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered; angle of chamfer with the top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced or with chamfered corners. Thickness of the washer face shall be approximately 1/64 in. included in the nut thickness, and diameter of washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

Finished regular nuts when specified shall be made to the dimensions given for the semifinished product, degree and character of finish to be specified in each case.

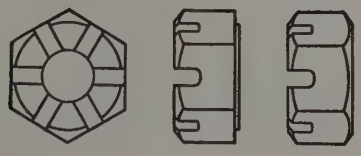


TABLE 9—*Dimensions of Regular Slotted Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS			SLOT	
		Max (basic)		Min	Min	Nom	Max	Min	Width	Depth
1/4	0.2500	7/16	0.4375	0.425	0.485	13/64	0.219	0.187	5/64	3/32
5/16	0.3125	9/16	0.5625	0.547	0.624	1/4	0.267	0.233	3/32	3/32
3/8	0.3750	5/8	0.6250	0.606	0.691	5/16	0.330	0.294	1/8	1/8
7/16	0.4375	3/4	0.7500	0.728	0.830	23/64	0.378	0.340	1/8	5/32
1/2	0.5000	13/16	0.8125	0.788	0.898	27/64	0.442	0.402	5/32	5/32
9/16	0.5625	7/8	0.8750	0.847	0.966	31/64	0.505	0.463	5/32	3/16
5/8	0.6250	1	1.0000	0.969	1.104	17/32	0.553	0.509	3/16	7/32
3/4	0.7500	1 1/8	1.1250	1.088	1.240	41/64	0.665	0.617	3/16	1/4
7/8	0.8750	1 5/16	1.3125	1.269	1.447	3/4	0.776	0.724	3/16	1/4
1	1.0000	1 1/2	1.5000	1.450	1.653	55/64	0.887	0.831	1/4	9/32
1 1/8	1.1250	1 11/16	1.6875	1.631	1.859	31/32	0.999	0.939	1/4	11/32
1 1/4	1.2500	1 7/8	1.8750	1.812	2.066	1 1/16	1.094	1.030	5/16	3/8
1 3/8	1.3750	2 1/16	2.0625	1.994	2.273	1 11/64	1.206	1.138	5/16	3/8
1 1/2	1.5000	2 1/4	2.2500	2.175	2.480	1 9/32	1.317	1.245	3/8	7/16
1 5/8	1.6250	2 7/16	2.4375	2.356	2.686	1 25/64	1.429	1.353	3/8	7/16
1 3/4	1.7500	2 5/8	2.6250	2.538	2.893	1 1/2	1.540	1.460	7/16	1/2
1 7/8	1.8750	2 13/16	2.8125	2.719	3.100	1 39/64	1.651	1.567	7/16	9/16
2	2.0000	3	3.0000	2.900	3.306	1 23/32	1.763	1.675	7/16	9/16
2 1/4	2.2500	3 3/8	3.3750	3.262	3.719	1 59/64	1.970	1.874	7/16	9/16
2 1/2	2.5000	3 3/4	3.7500	3.625	4.133	2 9/64	2.193	2.089	9/16	11/16
2 3/4	2.7500	4 1/8	4.1250	3.988	4.546	2 23/64	2.415	2.303	9/16	11/16
3	3.0000	4 1/2	4.5000	4.350	4.959	2 37/64	2.638	2.518	5/8	3/4

Regular nuts are for general use.

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered; angle of chamfer with the top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced or with chamfered corners. Thickness of the washer face shall be approximately 1/64 in., included in the nut thickness, and diameter of washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

Slots may have square or round bottoms at option of manufacturer.

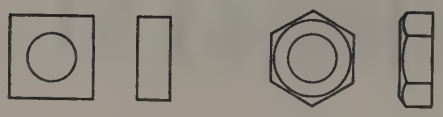


TABLE 10—*Dimensions of Machine-Screw and Stove-Bolt Nuts, Square and Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS, MIN		THICKNESS		
		Max (basic)		Min	Sq	Hex	Nom	Max	Min
No. 0	0.0600	5/32	0.1562	0.150	0.206	0.171	3/64	0.050	0.043
No. 1	0.0730	5/32	0.1562	0.150	0.206	0.171	3/64	0.050	0.043
No. 2	0.0860	3/16	0.1875	0.180	0.247	0.205	1/16	0.066	0.057
No. 3	0.0990	3/16	0.1875	0.180	0.247	0.205	1/16	0.066	0.057
No. 4	0.1120	1/4	0.2500	0.241	0.331	0.275	3/32	0.098	0.087
No. 5	0.1250	5/16	0.3125	0.302	0.415	0.344	7/64	0.114	0.102
No. 6	0.1380	5/16	0.3125	0.302	0.415	0.344	7/64	0.114	0.102
No. 8	0.1640	11/32	0.3438	0.332	0.456	0.378	1/8	0.130	0.117
No. 10	0.1900	3/8	0.3750	0.362	0.497	0.413	1/8	0.130	0.117
No. 12	0.2160	7/16	0.4375	0.423	0.581	0.482	5/32	0.161	0.148
1/4	0.2500	7/16	0.4375	0.423	0.581	0.482	3/16	0.193	0.178
5/16	0.3125	9/16	0.5625	0.545	0.748	0.621	7/32	0.225	0.208
3/8	0.3750	5/8	0.6250	0.607	0.833	0.692	1/4	0.257	0.239

Hexagon machine screw nuts shall have tops flat and chamfered; angle of chamfer with top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%. Bottoms are flat but for special purposes may be chamfered or washer faced if so specified.

Square machine-screw nuts and stove-bolt nuts shall have tops and bottoms flat without chamfer.

TABLE 11—*Dimensions of Heavy Nuts and Heavy Jam Nuts, Unfinished, Square, and Hexagon (Jam Nuts, Hexagon Only)*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS, MIN		THICKNESS, HEAVY NUTS			THICKNESS, HEAVY JAM NUTS		
		Max (basic)		Min	Sq	Hex	Nom	Max	Min	Nom	Max	Min
1/4	0.2500	1/2	0.5000	0.488	0.670	0.556	1/4	0.266	0.234	3/16	0.204	0.172
5/16	0.3125	19/32	0.5938	0.578	0.794	0.659	5/16	0.330	0.296	7/32	0.236	0.202
3/8	0.3750	11/16	0.6875	0.669	0.919	0.763	3/8	0.393	0.357	1/4	0.268	0.232
7/16	0.4375	25/32	0.7812	0.759	1.042	0.865	7/16	0.456	0.418	9/32	0.300	0.262
1/2	0.5000	7/8	0.8750	0.850	1.167	0.969	1/2	0.520	0.480	5/16	0.332	0.292
9/16	0.5625	15/16	0.9375	0.909	1.249	1.037	9/16	0.584	0.542	11/32	0.365	0.323
5/8	0.6250	1 1/16	1.0625	1.031	1.416	1.175	5/8	0.647	0.603	3/8	0.397	0.353
3/4	0.7500	1 1/4	1.2500	1.212	1.665	1.382	3/4	0.774	0.726	7/16	0.462	0.414
7/8	0.8750	1 7/16	1.4375	1.394	1.914	1.589	7/8	0.901	0.849	1/2	0.526	0.474
1	1.0000	1 5/8	1.6250	1.575	2.162	1.796	1	1.028	0.972	9/16	0.590	0.534
1 1/8	1.1250	1 13/16	1.8125	1.756	2.411	2.002	1 1/8	1.155	1.095	5/8	0.655	0.595
1 1/4	1.2500	2	2.0000	1.938	2.661	2.209	1 1/4	1.282	1.218	3/4	0.782	0.718
1 3/8	1.3750	2 3/16	2.1875	2.119	2.909	2.416	1 3/8	1.409	1.341	13/16	0.846	0.778
1 1/2	1.5000	2 3/8	2.3750	2.300	3.158	2.622	1 1/2	1.536	1.464	7/8	0.911	0.839
1 5/8	1.6250	2 9/16	2.5625	2.481	3.406	2.828	1 5/8	1.663	1.587	15/16	0.976	0.900
1 3/4	1.7500	2 3/4	2.7500	2.662	3.656	3.035	1 3/4	1.790	1.710	1	1.040	0.960
1 7/8	1.8750	2 15/16	2.9375	2.844	3.905	3.242	1 7/8	1.917	1.833	1 1/16	1.104	1.020
2	2.0000	3 1/8	3.1250	3.025	4.153	3.449	2	2.044	1.956	1 1/8	1.169	1.081
2 1/4	2.2500	3 1/2	3.5000	3.388	4.652	3.862	2 1/4	2.298	2.202	1 1/4	1.298	1.202
2 1/2	2.5000	3 7/8	3.8750	3.750	5.149	4.275	2 1/2	2.552	2.448	1 1/2	1.552	1.448
2 3/4	2.7500	4 1/4	4.2500	4.112	5.646	4.688	2 3/4	2.806	2.694	1 5/8	1.681	1.569
3	3.0000	4 5/8	4.6250	4.475	6.144	5.102	3	3.060	2.940	1 3/4	1.810	1.690
3 1/4	3.2500	5	5.0000	4.838	6.643	5.515	3 1/4	3.314	3.186	1 7/8	1.939	1.811
3 1/2	3.5000	5 3/8	5.3750	5.200	7.140	5.928	3 1/2	3.568	3.432	2	2.068	1.932
3 3/4	3.7500	5 3/4	5.7500	5.562	7.637	6.341	3 3/4	3.822	3.678	2 1/8	2.197	2.053
4	4.0000	6 1/8	6.1250	5.925	8.135	6.755	4	4.076	3.924	2 1/4	2.326	2.174

Heavy nuts are for use where greater bearing surface is necessary.

Unfinished nuts are not finished on any surface but are threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered or (except jam nuts) washer crowned. For flat and chamfered nuts the angle of chamfer with the top surface shall be 25 deg for square and 30 deg for hexagon; diameter of the top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 3 deg for 1-in. nuts or smaller and 2 deg for nuts larger than 1 in.

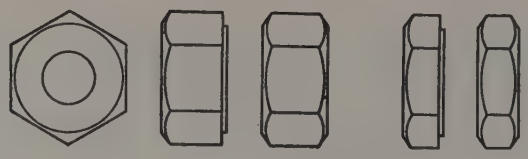


TABLE 12—*Dimensions of Heavy Nuts and Heavy Jam Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS, HEAVY NUTS			THICKNESS, HEAVY JAM NUTS		
		Max (basic)		Min	Min	Nom	Max	Min	Nom	Max	Min
1/4	0.2500	1/2	0.5000	0.488	0.556	15/64	0.250	0.218	11/64	0.188	0.156
5/16	0.3125	19/32	0.5938	0.578	0.659	19/64	0.314	0.280	13/64	0.220	0.186
3/8	0.3750	11/16	0.6875	0.669	0.763	23/64	0.377	0.341	15/64	0.252	0.216
7/16	0.4375	25/32	0.7812	0.759	0.865	27/64	0.441	0.403	17/64	0.285	0.247
1/2	0.5000	7/8	0.8750	0.850	0.969	31/64	0.504	0.464	19/64	0.317	0.277
9/16	0.5625	15/16	0.9375	0.909	1.037	35/64	0.568	0.526	21/64	0.349	0.307
5/8	0.6250	1 1/16	1.0625	1.031	1.175	39/64	0.631	0.587	23/64	0.381	0.337
3/4	0.7500	1 1/4	1.2500	1.212	1.382	47/64	0.758	0.710	27/64	0.446	0.398
7/8	0.8750	1 7/16	1.4375	1.394	1.589	55/64	0.885	0.833	31/64	0.510	0.458
1	1.0000	1 5/8	1.6250	1.575	1.796	63/64	1.012	0.956	35/64	0.575	0.519
1 1/8	1.1250	1 13/16	1.8125	1.756	2.002	1 7/64	1.139	1.079	39/64	0.639	0.579
1 1/4	1.2500	2	2.0000	1.938	2.209	1 7/32	1.251	1.187	23/32	0.751	0.687
1 3/8	1.3750	2 3/16	2.1875	2.119	2.416	1 11/32	1.378	1.310	25/32	0.815	0.747
1 1/2	1.5000	2 3/8	2.3750	2.300	2.622	1 15/32	1.505	1.433	27/32	0.880	0.808
1 5/8	1.6250	2 9/16	2.5625	2.481	2.828	1 19/32	1.632	1.556	29/32	0.944	0.868
1 3/4	1.7500	2 3/4	2.7500	2.662	3.035	1 23/32	1.759	1.679	31/32	1.009	0.929
1 7/8	1.8750	2 15/16	2.9375	2.844	3.242	1 27/32	1.886	1.802	1 1/32	1.073	0.989
2	2.0000	3 1/8	3.1250	3.025	3.449	1 31/32	2.013	1.925	1 3/32	1.138	1.050
2 1/4	2.2500	3 1/2	3.5000	3.388	3.862	2 13/64	2.251	2.155	1 13/64	1.251	1.155
2 1/2	2.5000	3 7/8	3.8750	3.750	4.275	2 29/64	2.505	2.401	1 29/64	1.505	1.401
2 3/4	2.7500	4 1/4	4.2500	4.112	4.688	2 45/64	2.759	2.647	1 37/64	1.634	1.522
3	3.0000	4 5/8	4.6250	4.475	5.102	2 61/64	3.013	2.893	1 45/64	1.763	1.643
3 1/4	3.2500	5	5.0000	4.838	5.515	3 3/16	3.252	3.124	1 13/16	1.876	1.748
3 1/2	3.5000	5 3/8	5.3750	5.200	5.928	3 7/16	3.506	3.370	1 15/16	2.006	1.870
3 3/4	3.7500	5 3/4	5.7500	5.562	6.341	3 11/16	3.760	3.616	2 1/16	2.134	1.990
4	4.0000	6 1/8	6.1250	5.925	6.755	3 15/16	4.014	3.862	2 3/16	2.264	2.112

Heavy nuts are for use where greater bearing surface is necessary.

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered; angle of chamfer with the top surface shall be 30 deg; diameter shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced or with chamfered corners. Thickness of the washer face shall be approximately 1/64 in. included in the nut thickness, and diameter of the washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

Finished heavy nuts when specified shall be made to the dimensions and tolerances given for the semifinished product, degree and character of finish to be specified in each case.

TABLE 13—*Dimensions of Heavy Slotted Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS			SLOT	
		Max (basic)		Min	Min	Nom	Max	Min	Width	Depth
1/4	0.2500	1/2	0.5000	0.488	0.556	15/64	0.250	0.218	5/64	3/32
5/16	0.3125	19/32	0.5938	0.578	0.659	19/64	0.314	0.280	3/32	3/32
3/8	0.3750	11/16	0.6875	0.669	0.763	23/64	0.377	0.341	1/8	1/8
7/16	0.4375	25/32	0.7812	0.759	0.865	27/64	0.441	0.403	1/8	5/32
1/2	0.5000	7/8	0.8750	0.850	0.969	31/64	0.504	0.464	5/32	5/32
9/16	0.5625	15/16	0.9375	0.909	1.037	35/64	0.568	0.526	5/32	3/16
5/8	0.6250	1 1/16	1.0625	1.031	1.175	39/64	0.631	0.587	3/16	7/32
3/4	0.7500	1 1/4	1.2500	1.212	1.382	47/64	0.758	0.710	3/16	1/4
7/8	0.8750	1 7/16	1.4375	1.394	1.589	55/64	0.885	0.833	3/16	1/4
1	1.0000	1 5/8	1.6250	1.575	1.796	63/64	1.012	0.956	1/4	9/32
1 1/8	1.1250	1 13/16	1.8125	1.756	2.002	1 7/64	1.139	1.079	1/4	11/32
1 1/4	1.2500	2	2.0000	1.938	2.209	1 7/32	1.251	1.187	5/16	3/8
1 3/8	1.3750	2 3/16	2.1875	2.119	2.416	1 11/32	1.378	1.310	5/16	3/8
1 1/2	1.5000	2 3/8	2.3750	2.300	2.622	1 15/32	1.505	1.433	3/8	7/16
1 5/8	1.6250	2 9/16	2.5625	2.481	2.828	1 19/32	1.632	1.556	3/8	7/16
1 3/4	1.7500	2 3/4	2.7500	2.662	3.035	1 23/32	1.759	1.679	7/16	1/2
1 7/8	1.8750	2 15/16	2.9375	2.844	3.242	1 27/32	1.886	1.802	7/16	9/16
2	2.0000	3 1/8	3.1250	3.025	3.449	1 31/32	2.013	1.925	7/16	9/16
2 1/4	2.2500	3 1/2	3.5000	3.388	3.862	2 13/64	2.251	2.155	7/16	9/16
2 1/2	2.5000	3 7/8	3.8750	3.750	4.275	2 29/64	2.505	2.401	9/16	11/16
2 3/4	2.7500	4 1/4	4.2500	4.112	4.688	2 45/64	2.759	2.647	9/16	11/16
3	3.0000	4 5/8	4.6250	4.475	5.102	2 61/64	3.013	2.893	5/8	3/4
3 1/4	3.2500	5	5.0000	4.838	5.515	3 3/16	3.252	3.124	5/8	3/4
3 1/2	3.5000	5 3/8	5.3750	5.200	5.928	3 7/16	3.506	3.370	5/8	3/4
3 3/4	3.7500	5 3/4	5.7500	5.562	6.341	3 11/16	3.760	3.616	5/8	3/4
4	4.0000	6 1/8	6.1250	5.925	6.755	3 15/16	4.014	3.862	5/8	3/4

Heavy nuts are for use where greater bearing surface is necessary.

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered; angle of chamfer with the top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced or with chamfered corners. Thickness of the washer face shall be approximately 1/64 in. included in the nut thickness, and diameter of the washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

Slots may have square or round bottom at option of manufacturer.

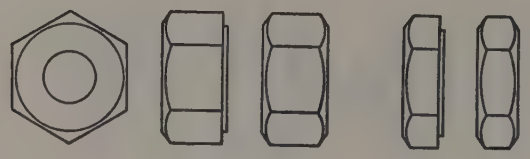


TABLE 14—*Dimensions of Light Nuts and Light Jam Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS, LIGHT NUTS			THICKNESS, LIGHT JAM NUTS		
		Max (basic)		Min	Min	Nom	Max	Min	Nom	Max	Min
1/4	0.2500	7/16	0.4375	0.428	0.488	7/32	0.226	0.212	5/32	0.163	0.150
5/16	0.3125	1/2	0.5000	0.489	0.557	17/64	0.273	0.258	3/16	0.195	0.180
3/8	0.3750	9/16	0.5625	0.551	0.628	21/64	0.337	0.320	7/32	0.227	0.210
7/16	0.4375	5/8	0.6250	0.612	0.698	3/8	0.385	0.365	1/4	0.260	0.240
1/2	0.5000	3/4	0.7500	0.736	0.840	7/16	0.448	0.427	5/16	0.323	0.302
9/16	0.5625	7/8	0.8750	0.861	0.982	31/64	0.496	0.473	5/16	0.324	0.301
5/8	0.6250	15/16	0.9375	0.922	1.051	35/64	0.559	0.534	3/8	0.387	0.363
3/4	0.7500	1 1/16	1.0625	1.045	1.191	21/32	0.670	0.642	3/8	0.389	0.361
7/8	0.8750	1 1/4	1.2500	1.231	1.403	49/64	0.782	0.750	7/16	0.454	0.421
1	1.0000	1 7/16	1.4375	1.417	1.615	7/8	0.893	0.857	1/2	0.518	0.482
1 1/8	1.1250	1 5/8	1.6250	1.602	1.826	63/64	1.004	0.964	9/16	0.582	0.543
1 1/4	1.2500	1 13/16	1.8125	1.788	2.038	1 3/32	1.116	1.072	5/8	0.647	0.603
1 3/8	1.3750	2	2.0000	1.973	2.249	1 13/64	1.227	1.180	3/4	0.774	0.726
1 1/2	1.5000	2 3/16	2.1875	2.159	2.461	1 5/16	1.338	1.287	13/16	0.838	0.787

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered; angle of chamfer with top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced or with chamfered corners. Thickness of the washer face shall be approximately 1/64 in. included in the nut thickness, and diameter of washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

TABLE 15—*Dimensions of Light Thick Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS		
		Max (basic)		Min	Min	Nom	Max	Min
1/4	0.2500	7/16	0.4375	0.428	0.488	9/32	0.288	0.274
5/16	0.3125	1/2	0.5000	0.489	0.557	21/64	0.336	0.320
3/8	0.3750	9/16	0.5625	0.551	0.628	13/32	0.415	0.398
7/16	0.4375	5/8	0.6250	0.612	0.698	29/64	0.463	0.444
1/2	0.5000	3/4	0.7500	0.736	0.840	9/16	0.573	0.552
9/16	0.5625	7/8	0.8750	0.861	0.982	37/64	0.621	0.598
5/8	0.6250	15/16	0.9375	0.922	1.051	23/32	0.731	0.706
3/4	0.7500	1 1/16	1.0625	1.045	1.191	13/16	0.827	0.798
7/8	0.8750	1 1/4	1.2500	1.231	1.403	29/32	0.922	0.890
1	1.0000	1 7/16	1.4375	1.417	1.615	1	1.018	0.982
1 1/8	1.1250	1 5/8	1.6250	1.602	1.826	1 5/32	1.176	1.136
1 1/4	1.2500	1 13/16	1.8125	1.788	2.038	1 1/4	1.272	1.228
1 3/8	1.3750	2	2.0000	1.973	2.249	1 3/8	1.399	1.351
1 1/2	1.5000	2 3/16	2.1875	2.159	2.461	1 1/2	1.526	1.474

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered; angle of chamfer with top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced or with chamfered corners. Thickness of the washer face shall be approximately 1/64 in. included in the nut thickness, and diameter of the washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

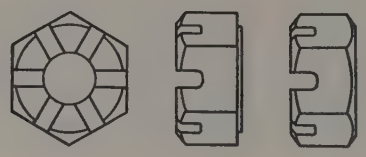


TABLE 16—*Dimensions of Light Slotted Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS			SLOT	
		Max (basic)		Min	Min	Nom	Max	Min	Width	Depth
1/4	0.2500	7/16	0.4375	0.428	0.488	7/32	0.226	0.212	5/64	3/32
5/16	0.3125	1/2	0.5000	0.489	0.557	17/64	0.273	0.258	3/32	3/32
3/8	0.3750	9/16	0.5625	0.551	0.628	21/64	0.337	0.320	1/8	1/8
7/16	0.4375	5/8	0.6250	0.612	0.698	3/8	0.385	0.365	1/8	5/32
1/2	0.5000	3/4	0.7500	0.736	0.840	7/16	0.448	0.427	5/32	5/32
9/16	0.5625	7/8	0.8750	0.861	0.982	31/64	0.496	0.473	5/32	3/16
5/8	0.6250	15/16	0.9375	0.922	1.051	35/64	0.559	0.534	3/16	7/32
3/4	0.7500	1 1/16	1.0625	1.045	1.191	21/32	0.670	0.642	3/16	1/4
7/8	0.8750	1 1/4	1.2500	1.231	1.403	49/64	0.782	0.750	3/16	1/4
1	1.0000	1 1/16	1.4375	1.417	1.615	7/8	0.893	0.857	1/4	9/32
1 1/8	1.1250	1 5/8	1.6250	1.602	1.826	63/64	1.004	0.964	1/4	11/32
1 1/4	1.2500	1 13/16	1.8125	1.788	2.038	1 3/32	1.116	1.072	5/16	3/8
1 3/8	1.3750	2	2.0000	1.973	2.249	1 13/64	1.227	1.180	5/16	3/8
1 1/2	1.5000	2 3/16	2.1875	2.159	2.461	1 5/16	1.338	1.287	3/8	7/16

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered; angle of chamfer with top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats within a tolerance of minus 15%.

Bearing surface shall be washer faced or with chamfered corners. Thickness of the washer face shall be approximately 1/64 in. included in the nut thickness, and diameter of the washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

Slots may have square or round bottoms at option of manufacturer.

TABLE 17—*Dimensions of Light Thick Slotted Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS			SLOT	
		Max (basic)		Min	Min	Nom	Max	Min	Width	Depth
1/4	0.2500	7/16	0.4375	0.428	0.488	9/32	0.288	0.274	5/64	3/32
5/16	0.3125	1/2	0.5000	0.489	0.557	21/64	0.336	0.320	3/32	3/32
3/8	0.3750	9/16	0.5625	0.551	0.628	13/32	0.415	0.398	1/8	1/8
7/16	0.4375	5/8	0.6250	0.612	0.698	29/64	0.463	0.444	1/8	5/32
1/2	0.5000	3/4	0.7500	0.736	0.840	9/16	0.573	0.552	5/32	5/32
9/16	0.5625	7/8	0.8750	0.861	0.982	37/64	0.621	0.598	5/32	3/16
5/8	0.6250	15/16	0.9375	0.922	1.051	23/32	0.731	0.706	3/16	7/32
3/4	0.7500	1 1/16	1.0625	1.045	1.191	13/16	0.827	0.798	3/16	1/4
7/8	0.8750	1 1/4	1.2500	1.231	1.403	29/32	0.922	0.890	3/16	1/4
1	1.0000	1 7/16	1.4375	1.417	1.615	1	1.018	0.982	1/4	9/32
1 1/8	1.1250	1 5/8	1.6250	1.602	1.826	1 5/32	1.176	1.136	1/4	11/32
1 1/4	1.2500	1 13/16	1.8125	1.788	2.038	1 1/4	1.272	1.228	5/16	3/8
1 3/8	1.3750	2	2.0000	1.973	2.249	1 3/8	1.399	1.351	5/16	3/8
1 1/2	1.5000	2 3/16	2.1875	2.159	2.461	1 1/2	1.526	1.474	3/8	7/16

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Tops of nuts shall be flat and chamfered; angle of chamfer with top surface shall be 30 deg; diameter of top circle shall be the maximum width across flats with a tolerance of minus 15%.

Bearing surface shall be washer faced or with chamfered corners. Thickness of the washer face shall be approximately 1/64 in. included in the nut thickness, and diameter of the washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

Slots may have square or round bottoms at option of manufacturer.

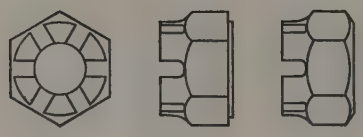


TABLE 18—*Dimensions of Light Castle Nuts, Semifinished, Hexagon*

NOMINAL SIZE OR BASIC MAJOR DIAMETER OF THREAD		WIDTH ACROSS FLATS			WIDTH ACROSS CORNERS	THICKNESS			NOMINAL HEIGHT OF FLATS[a]	SLOT		RADIUS OF FILLET[b]	DIAMETER OF CYLINDRICAL PART[c]
		Max (basic)		Min	Min	Nom	Max	Min		Width	Depth		Min
1/4	0.2500	7/16	0.4375	0.428	0.488	9/32	0.288	0.274	3/16	5/64	3/32	3/32	0.371
5/16	0.3125	1/2	0.5000	0.489	0.557	21/64	0.336	0.320	15/64	3/32	3/32	3/32	0.425
3/8	0.3750	9/16	0.5625	0.551	0.628	13/32	0.415	0.398	9/32	1/8	1/8	3/32	0.478
7/16	0.4375	5/8	0.6250	0.612	0.698	29/64	0.463	0.444	19/64	1/8	5/32	3/32	0.531
1/2	0.5000	3/4	0.7500	0.736	0.840	9/16	0.573	0.552	13/32	5/32	5/32	1/8	0.637
9/16	0.5625	7/8	0.8750	0.861	0.982	39/64	0.621	0.598	27/64	5/32	3/16	5/32	0.744
5/8	0.6250	15/16	0.9375	0.922	1.051	23/32	0.731	0.706	1/2	3/16	7/32	5/32	0.797
3/4	0.7500	1 1/16	1.0625	1.045	1.191	13/16	0.827	0.798	9/16	3/16	1/4	3/16	0.903
7/8	0.8750	1 1/4	1.2500	1.231	1.403	29/32	0.922	0.890	21/32	3/16	1/4	3/16	1.063
1	1.0000	1 7/16	1.4375	1.417	1.615	1	1.018	0.982	23/32	1/4	9/32	3/16	1.222
1 1/8	1.1250	1 5/8	1.6250	1.602	1.826	1 5/32	1.176	1.136	13/16	1/4	11/32	1/4	1.382
1 1/4	1.2500	1 13/16	1.8125	1.788	2.038	1 1/4	1.272	1.228	7/8	5/16	3/8	1/4	1.541
1 3/8	1.3750	2	2.0000	1.973	2.249	1 3/8	1.399	1.351	1	5/16	3/8	1/4	1.700
1 1/2	1.5000	2 3/16	2.1875	2.159	2.461	1 1/2	1.526	1.474	1 1/16	3/8	7/16	1/4	1.859

[a] Height of the hexagon is measured from the bearing surface to top of arc.
[b] Tolerance on the fillet radius is plus or minus 0.010.
[c] Maximum diameter of cylindrical part shall not exceed maximum width across flats.

Semifinished nuts are finished on bearing surface and threaded.

Taper of the sides of nuts (angle between one side and the axis) shall not exceed 2 deg, the specified width across flats being the largest dimension.

Bearing surface shall be washer faced or with chamfered corners. The thickness of the washer face shall be approximately 1/64 in. included in the nut thickness, and diameter of the washer face shall be the maximum width across flats within a tolerance of minus 5%.

Bearing surface shall be at right angles to the axis of the threaded hole within a tolerance of 2 deg for 1-in. nuts or smaller and 1 deg for nuts larger than 1 in.

Slots may have square or round bottoms at option of manufacturer.

TABLE 19—*Open-End Wrench Openings for Regular, Heavy, and Light Series Bolts and Nuts*

NOMINAL SIZE OF WRENCH,[a] ALSO BASIC OR MAXIMUM WIDTH ACROSS FLATS, BOLT HEADS AND NUTS		ALLOWANCE BETWEEN BOLT HEAD OR NUT AND JAWS OF WRENCH[b]	WRENCH OPENINGS[c]			NOMINAL BOLT DIAMETER						
						Regular series		Heavy series	Light series			
			Min	Tolerance	Max	Bolts	Nuts, jam nuts, and slotted nuts	Bolts, nuts, jam nuts, slotted nuts	Nuts, jam nuts, castle nuts, and slotted nuts	Cap-screws	Set-screws	Machine-screw nuts and stove-bolt nuts
5/32	0.1562	0.002	0.158	0.005	0.163	—	—	—	—	—	—	No. 0 & No. 1
3/16	0.1875	0.002	0.190	0.005	0.195	—	—	—	—	—	—	No. 2 & No. 3
1/4	0.2500	0.002	0.252	0.005	0.257	—	—	—	—	—	1/4	No. 4
5/16	0.3125	0.003	0.316	0.006	0.322	—	—	—	—	—	5/16	No. 5 & No. 6
11/32	0.3438	0.003	0.347	0.006	0.353	—	—	—	—	—	—	No. 8
3/8	0.3750	0.003	0.378	0.006	0.384	1/4	—	—	—	—	3/8	No. 10
7/16	0.4375	0.003	0.440	0.006	0.446	—	1/4	—	1/4	1/4	7/16	No. 12 & 1/4
1/2	0.5000	0.004	0.504	0.006	0.510	5/16	—	1/4	5/16	5/16	1/2	—
9/16	0.5625	0.004	0.566	0.007	0.573	3/8	5/16	—	3/8	3/8	9/16	5/16
19/32	0.5938	0.004	0.598	0.007	0.605	—	—	5/16	—	—	—	—
5/8	0.6250	0.004	0.629	0.007	0.636	7/16	3/8	—	7/16	7/16	5/8	3/8
11/16	0.6875	0.004	0.692	0.007	0.699	—	—	3/8	—	—	—	—
3/4	0.7500	0.005	0.755	0.008	0.763	1/2	7/16	—	1/2	1/2	3/4	—
25/32	0.7812	0.005	0.786	0.008	0.794	—	—	7/16	—	—	—	—
13/16	0.8125	0.005	0.818	0.008	0.826	—	1/2	—	—	9/16	—	—
7/8	0.8750	0.005	0.880	0.008	0.888	9/16	9/16	1/2	9/16	5/8	7/8	—
15/16	0.9375	0.006	0.944	0.009	0.953	5/8	—	9/16	5/8	—	—	—
1	1.0000	0.006	1.006	0.009	1.015	—	5/8	—	—	3/4	1	—
1 1/16	1.0625	0.006	1.068	0.009	1.077	—	—	5/8	3/4	—	—	—
1 1/8	1.1250	0.007	1.132	0.010	1.142	3/4	3/4	—	—	7/8	1 1/8	—
1 1/4	1.2500	0.007	1.257	0.010	1.267	—	—	3/4	7/8	—	1 1/4	—
1 5/16	1.3125	0.008	1.320	0.011	1.331	7/8	7/8	—	—	1	—	—
1 3/8	1.3750	0.008	1.383	0.011	1.394	—	—	—	—	—	1 3/8	—
1 7/16	1.4375	0.008	1.446	0.011	1.457	—	—	7/8	1	—	—	—
1 1/2	1.5000	0.008	1.508	0.012	1.520	1	1	—	—	1 1/8	1 1/2	—
1 5/8	1.6250	0.009	1.634	0.012	1.646	—	—	1	1 1/8	—	—	—
1 11/16	1.6875	0.009	1.696	0.012	1.708	1 1/8	1 1/8	—	—	1 1/4	—	—
1 13/16	1.8125	0.010	1.822	0.013	1.835	—	—	1 1/8	1 1/4	—	—	—
1 7/8	1.8750	0.010	1.885	0.013	1.898	1 1/4	1 1/4	—	—	—	—	—
2	2.0000	0.011	2.011	0.014	2.025	—	—	1 1/4	1 3/8	—	—	—
2 1/16	2.0625	0.011	2.074	0.014	2.088	1 3/8	1 3/8	—	—	—	—	—
2 3/16	2.1875	0.012	2.200	0.015	2.215	—	—	1 3/8	1 1/2	—	—	—
2 1/4	2.2500	0.012	2.262	0.015	2.277	1 1/2	1 1/2	—	—	—	—	—
2 3/8	2.3750	0.013	2.388	0.016	2.404	—	—	1 1/2	—	—	—	—
2 7/16	2.4375	0.013	2.450	0.016	2.466	1 5/8	1 5/8	—	—	—	—	—
2 9/16	2.5625	0.014	2.576	0.017	2.593	—	—	1 5/8	—	—	—	—
2 5/8	2.6250	0.014	2.639	0.017	2.656	1 3/4	1 3/4	—	—	—	—	—
2 3/4	2.7500	0.014	2.766	0.017	2.783	—	—	1 3/4	—	—	—	—
2 13/16	2.8125	0.015	2.827	0.018	2.845	1 7/8	1 7/8	—	—	—	—	—
2 15/16	2.9375	0.016	2.954	0.019	2.973	—	—	1 7/8	—	—	—	—
3	3.0000	0.016	3.016	0.019	3.035	2	2	—	—	—	—	—
3 1/8	3.1250	0.017	3.142	0.020	3.162	—	—	2	—	—	—	—
3 3/8	3.3750	0.018	3.393	0.021	3.414	2 1/4	2 1/4	—	—	—	—	—
3 1/2	3.5000	0.019	3.518	0.022	3.540	—	—	2 1/4	—	—	—	—
3 3/4	3.7500	0.020	3.770	0.023	3.793	2 1/2	2 1/2	—	—	—	—	—
3 7/8	3.8750	0.020	3.895	0.023	3.918	—	—	2 1/2	—	—	—	—
4 1/8	4.1250	0.022	4.147	0.025	4.172	2 3/4	2 3/4	—	—	—	—	—
4 1/4	4.2500	0.022	4.272	0.025	4.297	—	—	2 3/4	—	—	—	—
4 1/2	4.5000	0.024	4.524	0.026	4.550	3	3	—	—	—	—	—
4 5/8	4.6250	0.024	4.649	0.027	4.676	—	—	3	—	—	—	—
5	5.0000	0.026	5.026	0.029	5.055	—	—	3 1/4	—	—	—	—
5 3/8	5.3750	0.028	5.403	0.031	5.434	—	—	3 1/2	—	—	—	—
5 3/4	5.7500	0.030	5.780	0.033	5.813	—	—	3 3/4	—	—	—	—
6 1/8	6.1250	0.032	6.157	0.035	6.192	—	—	4	—	—	—	—

[a] Wrenches shall be marked with the "Nominal Size of Wrench" which is equal to the basic or maximum width across flats of the corresponding bolt head or nut.
[b] Allowance (minimum clearance) between maximum width across flats of nut or bolt head and jaws of wrench equals $(1.005\ W + 0.001)$.
[c] Tolerance on wrench opening equals plus $(0.005\ W + 0.004)$ from minimum (W equals nominal size of wrench).

TABLE 20a—*Formulas for Bolt, Capscrew, and Setscrew Heads (Dimensions and Tolerances Given in Tables 1 to 6 Inclusive Based on Formulas Tabulated Below)*

TYPE OF HEAD	WIDTH ACROSS FLATS, SQUARE AND HEXAGON		HEIGHT OF HEAD, SQUARE AND HEXAGON		WIDTH ACROSS CORNERS, MIN	
	Basic[a]	Tolerance, minus	Nominal[b]	Tolerance, plus or minus	Square	Hexagon
Regular Unfinished (Table 1)	$1\frac{1}{2}D$	$0.050D$	$\frac{2}{3}D$	$0.016D + 0.012$	For all square bolt heads, min width across corners equals $1.373 \times W$ (min)	For all hexagon bolt heads, min width across corners equals $1.14 \times W$ (min)
Semifinished (also finished) (Table 2)	$1\frac{1}{2}D$	$0.050D$	Size / H: $\frac{1}{4}$ to $\frac{7}{16}$: $\frac{2}{3}D - \frac{1}{64}$; $\frac{1}{2}$ to $\frac{7}{8}$: $\frac{2}{3}D - \frac{1}{32}$; 1 to $1\frac{7}{8}$: $\frac{2}{3}D - \frac{1}{16}$; 2 to 3: $\frac{2}{3}D - \frac{1}{8}$	$0.016D + 0.012$		
Heavy Unfinished (Table 3)	$1\frac{1}{2}D + \frac{1}{8}$	$0.050D$	$\frac{3}{4}D + \frac{1}{16}$	$0.016D + 0.012$		
Semifinished (also finished) (Table 4)	$1\frac{1}{2}D + \frac{1}{8}$	$0.050D$	Size / H: $\frac{1}{2}$ to $\frac{7}{8}$: $\frac{3}{4}D - \frac{1}{32}$; 1 to $1\frac{7}{8}$: $\frac{3}{4}D$; 2 to 3: $\frac{3}{4}D - \frac{1}{16}$	$0.016D + 0.012$		
Capscrew (Table 5)	Size / W: $\frac{1}{4}$ to $\frac{7}{16}$: $D + \frac{3}{16}$; $\frac{1}{2}$ to $\frac{7}{8}$: $D + \frac{1}{4}$; 1: $D + \frac{5}{16}$; $1\frac{1}{8}$: $D + \frac{3}{8}$; $1\frac{1}{4}$: $D + \frac{7}{16}$	$0.015D + 0.006$	$\frac{3}{4}D$	$0.015D + 0.003$		
Setscrew (Table 6)	D	Size / Tolerance: $\frac{1}{4}$ and $\frac{5}{16}$: (See Table); $\frac{3}{8}$ to $1\frac{1}{2}$: $0.020D + 0.006$	$\frac{3}{4}D$	$0.020D + 0.004$		

[a] Adjusted to sixteenths.
[b] Adjusted to fractions.
D equals nominal size of bolt; W equals width across flats; H equals height of head.

TABLE 20b—*Formulas for Nuts (Dimensions and Tolerances Given in Tables 7 to 18 Inclusive Based on Formulas Tabulated Below)*

TYPE OF NUT	WIDTH ACROSS FLATS, SQUARE AND HEXAGON		THICKNESS OF NUT, SQUARE AND HEXAGON		WIDTH ACROSS CORNERS, MIN	
	Basic[a]	Tolerance, minus	Nominal[b]	Tolerance, plus or minus	Square	Hexagon
	Size *W*					
Regular						
Unfinished (Table 7)	¼ to ⅝ $1\frac{1}{2}D + \frac{1}{16}$ ¾ to 3 $1\frac{1}{2}D$	0.050*D*	$\frac{7}{8}D$	0.016*D* + 0.012		
			Size *N*			
Unfinished jam (Table 7)	¼ to ⅝ $1\frac{1}{2}D + \frac{1}{16}$ ¾ to 3 $1\frac{1}{2}D$	0.050*D*	¼ to 7/16 $\frac{1}{2}D + \frac{1}{32}$ ½ to 1⅛ $\frac{1}{2}D + \frac{1}{16}$ 1¼ to 2¼ $\frac{1}{2}D + \frac{1}{8}$ 2½ to 3 $\frac{1}{2}D + \frac{1}{4}$	0.016*D* + 0.012		
Semifinished, hexagon only (also finished)	¼ to ⅝ $1\frac{1}{2}D + \frac{1}{16}$	0.050*D*	¼ to 1⅛ $\frac{7}{8}D - \frac{1}{64}$	0.016*D* + 0.012	For all square nuts, min width across corners equals 1.373 × *W* (min)	For all hexagon nuts, min width across corners equals 1.14 × *W* (min)
Plain—Table 8	¾ to 3 $1\frac{1}{2}D$		1¼ to 2 $\frac{7}{8}D - \frac{1}{32}$			
Slotted—Table 9			2¼ to 3 $\frac{7}{8}D - \frac{3}{64}$			
Semifinished jam, hexagon only (also finished) (Table 8)	¼ to ⅝ $1\frac{1}{2}D + \frac{1}{16}$ ¾ to 3 $1\frac{1}{2}D$	0.050*D*	¼ to 7/16 $\frac{1}{2}D + \frac{1}{64}$ ½ to 1⅛ $\frac{1}{2}D + \frac{3}{64}$ 1¼ to 2 $\frac{1}{2}D + \frac{3}{32}$ 2¼ $\frac{1}{2}D + \frac{5}{64}$ 2½ to 3 $\frac{1}{2}D + \frac{13}{64}$	0.016*D* + 0.012		
Machine Screw and Stove Bolt (Table 10)	No. 0 to No. 12 (See Table) ¼ to ⅜ $1\frac{1}{2}D + \frac{1}{16}$	(See Table)	(See Table)	(See Table)		

(*Table 20b continued on next page.*)

TABLE 20b—*Formulas for Nuts (Dimensions and Tolerances Given in Tables 7 to 18 Inclusive Based on Formulas Tabulated Below)(Concluded)*

TYPE OF NUT	WIDTH ACROSS FLATS, SQUARE AND HEXAGON		THICKNESS OF NUT, SQUARE AND HEXAGON		WIDTH ACROSS CORNERS, MIN	
	Basic[a]	Tolerance, minus	Nominal[b]	Tolerance, plus or minus	Square	Hexagon
Heavy						
Unfinished (Table 11)	$1\frac{1}{2}D + \frac{1}{8}$	$0.050D$	D	$0.016D + 0.012$		
			Size — N			
Unfinished jam, hexagon only (Table 11)	$1\frac{1}{2}D + \frac{1}{8}$	$0.050D$	$\frac{1}{4}$ to $1\frac{1}{8}$ — $\frac{1}{2}D + \frac{1}{16}$ $1\frac{1}{4}$ to $2\frac{1}{4}$ — $\frac{1}{2}D + \frac{1}{8}$ $2\frac{1}{2}$ to 4 — $\frac{1}{2}D + \frac{1}{4}$	$0.016D + 0.012$		
Semifinished, hexagon only (also finished)	$1\frac{1}{2}D + \frac{1}{8}$	$0.050D$	$\frac{1}{4}$ to $1\frac{1}{8}$ — $D - \frac{1}{64}$ $1\frac{1}{4}$ to 2 — $D - \frac{1}{32}$ $2\frac{1}{4}$ to 3 — $D - \frac{3}{64}$ $3\frac{1}{4}$ to 4 — $D - \frac{1}{16}$	$0.016D + 0.012$	For all square nuts, min width across corners equals $1.373 \times W$ (min)	For all hexagon nuts, min width across corners equals $1.14 \times W$ (min)
Plain—Table 12						
Slotted—Table 13						
Semifinished jam, hexagon only (also finished) (Table 12)	$1\frac{1}{2}D + \frac{1}{8}$	$0.050D$	$\frac{1}{4}$ to $1\frac{1}{8}$ — $\frac{1}{2}D + \frac{3}{64}$ $1\frac{1}{4}$ to 2 — $\frac{1}{2}D + \frac{3}{32}$ $2\frac{1}{4}$ — $\frac{1}{2}D + \frac{5}{64}$ $2\frac{1}{2}$ to 3 — $\frac{1}{2}D + \frac{13}{64}$ $3\frac{1}{4}$ to 4 — $\frac{1}{2}D + \frac{3}{16}$	$0.016D + 0.012$		
Light	(See Table)	$0.015D + 0.006$	$\frac{7}{8}D$	$0.015D + 0.003$		
Plain—Table 14						
Slotted—Table 16						
Jam (Table 14)	(See Table)	$0.015D + 0.006$	(See Table)	$0.015D + 0.003$		
Thick	(See Table)	$0.015D + 0.006$	(See Table)	$0.015D + 0.003$		
Plain—Table 15			(same as Castle)			
Slotted—Table 17						
Castle (Table 18)	(See Table)	$0.015D + 0.006$	(See Table) (same as Thick Nut)	$0.015D + 0.003$		

[a] Adjusted to sixteenths except for heavy series below ½-in. size.
[b] Adjusted to fractions.
D equals nominal size of bolt; W equals width across flats; N equals thickness of nut.

Slotted- and Recessed-Head Screws

SAE Standard

Report of Screw Threads Technical Committee approved October 1947. This SAE Standard conforms with American Standard Slotted and Recessed Head Screws, ASA B18.6—1947.

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Scope—This SAE Standard is intended to cover the head dimensions, body diameters, screw lengths, and thread lengths of the various types of machine, cap, wood, tapping, and headless set screws.

Machine Screws—General Data (Tables 1 through 11)

Bearing Surface—The bearing surface of machine-screw heads, except flat and oval heads shall be at right angles to the body within 2 deg.

Eccentricity—The heads of machine screws shall not be eccentric with the body beyond a tolerance of 3% of the maximum head diameter.

Radius of the Fillet Under the Head—Radius of fillet under the head of machine screws shall not exceed one half of the pitch of the thread, except for flat and oval head, which shall not exceed two times the pitch of the thread.

Depth of Slots—The depth of slots is measured from the highest part of the head to the intersection of the bottom of the slot with the head surface.

Unthreaded Diameter—The diameter of the unthreaded portion of machine screws shall not be less than the minimum pitch diameter nor more than the maximum major thread diameter.

Length of Machine Screw—The length of machine screws shall be measured from the largest diameter of the bearing surface of the head to the extreme point, in a line parallel to the axis of the screw

Tolerance in Length—The length of machine screws shall not vary from that specified by more than the following: up to 1 in. in length, minus $\frac{1}{32}$ in.; over 1 in. to 2 in., inclusive, minus $\frac{1}{16}$ in.; over 2 in., minus $\frac{3}{32}$ in.

Length of Thread—On machine screws 2 in. long and shorter, the complete threads shall extend to within two threads of the bearing surface of the head or closer if practicable. Screws of longer length shall have a minimum complete thread length of $1\frac{3}{4}$ in.

Points—Machine screws are regularly supplied with a plain sheared end, not pointed. Header points are obtainable up to certain lengths for specific applications (Table 11). Pointing of longer lengths will require machining.

Thread Series and Tolerances—The screw threads on machine screws shall be either the American National Coarse (NC-2) or the American National Fine-Thread Series (NF-2), Class 2.

Finish—Machine screws are regularly supplied with a naturally bright finish, not heat-treated.

Header Points—See Table 11.

All table dimensions are in inches.

(*Tables begin on next page.*)

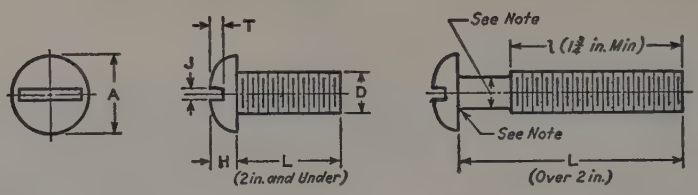
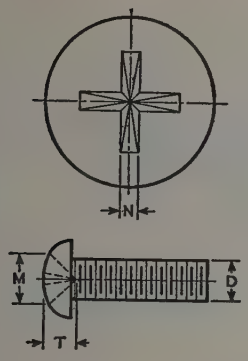


TABLE 1—*Dimensions of Round-Head Machine Screws*

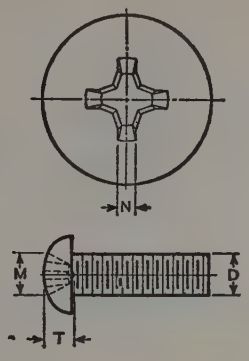
NOMINAL SIZE	*D*	*A*		*H*		*J*		*T*	
	Max diameter of screw	Head diameter		Height of head		Width of slot		Depth of slot	
		Max	Min	Max	Min	Max	Min	Max	Min
0	0.060	0.113	0.099	0.053	0.043	0.023	0.016	0.039	0.029
1	0.073	0.138	0.122	0.061	0.051	0.026	0.019	0.044	0.033
2	0.086	0.162	0.146	0.069	0.059	0.031	0.023	0.048	0.037
3	0.099	0.187	0.169	0.078	0.067	0.035	0.027	0.053	0.040
4	0.112	0.211	0.193	0.086	0.075	0.039	0.031	0.058	0.044
5	0.125	0.236	0.217	0.095	0.083	0.043	0.035	0.063	0.047
6	0.138	0.260	0.240	0.103	0.091	0.048	0.039	0.068	0.051
8	0.164	0.309	0.287	0.120	0.107	0.054	0.045	0.077	0.058
10	0.190	0.359	0.334	0.137	0.123	0.060	0.050	0.087	0.065
12	0.216	0.408	0.382	0.153	0.139	0.067	0.056	0.096	0.072
¼	0.250	0.472	0.443	0.175	0.160	0.075	0.064	0.109	0.082
5/16	0.3125	0.590	0.557	0.216	0.198	0.084	0.072	0.132	0.099
⅜	0.375	0.708	0.670	0.256	0.237	0.094	0.081	0.155	0.117
7/16	0.4375	0.750	0.707	0.328	0.307	0.094	0.081	0.196	0.148
½	0.500	0.813	0.766	0.355	0.332	0.106	0.091	0.211	0.159
9/16	0.5625	0.938	0.887	0.410	0.385	0.118	0.102	0.242	0.183
⅝	0.625	1.000	0.944	0.438	0.411	0.133	0.116	0.258	0.195
¾	0.750	1.250	1.185	0.547	0.516	0.149	0.131	0.320	0.242

Note—Refer to Machine Screws—General Data.

Head dimensions for sizes 7/16 in. and larger are in agreement with round-head cap screw dimensions, except that the minimum values have been decreased to provide tolerances in proportion to balance of table.



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 1a—*Cross-Recess Dimensions of Round-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	0.073	0.064	0.048	0.009	
1	0.073	0.090	0.079	0.059	0.012	
2	0.086	0.105	0.095	0.068	0.015	
3	0.099	0.122	0.110	0.079	0.018	
4	0.112	0.137	0.125	0.089	0.021	
5	0.125	0.153	0.141	0.100	0.024	
6	0.138	0.169	0.156	0.110	0.027	
8	0.164	0.201	0.186	0.131	0.032	Point same on all drivers
10	0.190	0.233	0.217	0.152	0.038	
12	0.216	0.265	0.248	0.173	0.044	
1/4	0.250	0.306	0.288	0.199	0.051	
5/16	0.3125	0.384	0.362	0.250	0.065	
3/8	0.375	0.460	0.436	0.299	0.078	
7/16	0.4375	0.487	0.460	0.316	0.083	
1/2	0.500	0.528	0.497	0.343	0.089	
9/16	0.5625	0.609	0.575	0.397	0.104	
5/8	0.625	0.650	0.614	0.424	0.112	
3/4	0.750	0.650	0.614	0.424	0.112	

TABLE 1b—*Cross-Recess Dimensions of Round-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	—	—	—	—	—
1	0.073	—	—	—	—	—
2	0.086	0.097	0.087	0.071	0.017	1
3	0.099	0.106	0.096	0.080	0.018	1
4	0.112	0.115	0.105	0.090	0.017	1
5	0.125	0.151	0.141	0.104	0.027	2
6	0.138	0.159	0.149	0.112	0.027	2
8	0.164	0.175	0.165	0.128	0.030	2
10	0.190	0.192	0.182	0.145	0.031	2
12	0.216	0.246	0.236	0.165	0.036	3
1/4	0.250	0.265	0.255	0.187	0.037	3
5/16	0.3125	0.305	0.295	0.227	0.043	3
3/8	0.375	0.384	0.374	0.281	0.064	4
7/16	0.4375	0.399	0.389	0.297	0.066	4
1/2	0.500	0.413	0.403	0.314	0.068	4
9/16	0.5625	0.458	0.448	0.360	0.075	4
5/8	0.625	0.606	0.586	0.397	0.083	5
3/4	0.750	0.713	0.693	0.502	0.095	5

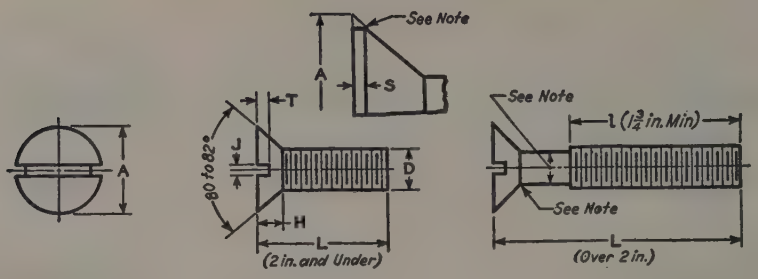


TABLE 2—*Dimensions of Flat-Head Machine Screws*

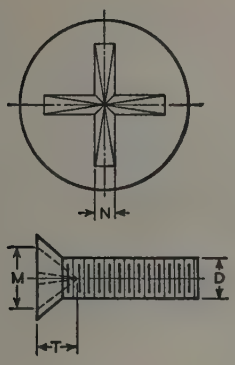
NOMINAL SIZE	D	A			S	H		J		T	
	Max diameter of screw	Head diameter			Flat on min screw	Height of head		Width of slot		Depth of slot	
		Max sharp	Min sharp	Absolute min with max S		Max	Min	Max	Min	Max	Min
0	0.060	0.119	0.105	0.101	0.002	0.035	0.026	0.023	0.016	0.015	0.010
1	0.073	0.146	0.130	0.126	0.003	0.043	0.033	0.026	0.019	0.019	0.012
2	0.086	0.172	0.156	0.150	0.003	0.051	0.040	0.031	0.023	0.023	0.015
3	0.099	0.199	0.181	0.175	0.004	0.059	0.048	0.035	0.027	0.027	0.017
4	0.112	0.225	0.207	0.200	0.004	0.067	0.055	0.039	0.031	0.030	0.020
5	0.125	0.252	0.232	0.225	0.005	0.075	0.062	0.043	0.035	0.034	0.022
6	0.138	0.279	0.257	0.249	0.005	0.083	0.069	0.048	0.039	0.038	0.024
8	0.164	0.332	0.308	0.300	0.006	0.100	0.084	0.054	0.045	0.045	0.029
10	0.190	0.385	0.359	0.348	0.007	0.116	0.098	0.060	0.050	0.053	0.034
12	0.216	0.438	0.410	0.397	0.008	0.132	0.112	0.067	0.056	0.060	0.039
¼	0.250	0.507	0.477	0.462	0.009	0.153	0.131	0.075	0.064	0.070	0.046
5/16	0.3125	0.635	0.600	0.581	0.011	0.191	0.165	0.084	0.072	0.088	0.058
⅜	0.375	0.762	0.722	0.700	0.013	0.230	0.200	0.094	0.081	0.106	0.070
7/16	0.4375	0.812	0.771	0.743	0.016	0.223	0.190	0.094	0.081	0.103	0.066
½	0.500	0.875	0.831	0.802	0.018	0.223	0.186	0.106	0.091	0.103	0.065
9/16	0.5625	1.000	0.950	0.919	0.020	0.260	0.220	0.118	0.102	0.120	0.077
⅝	0.625	1.125	1.069	1.035	0.023	0.298	0.253	0.133	0.116	0.137	0.088
¾	0.750	1.375	1.306	1.267	0.027	0.372	0.319	0.149	0.131	0.171	0.111

Note—Refer to Machine Screws—General Data.

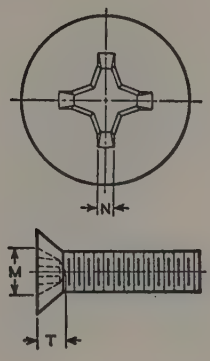
Edges of head may be rounded.

Short-length flat-head screws with a length equal to or less than the accompanying list have undercut heads, with the conical bearing surface approximately two thirds of the standard height, with slot depths and recess dimensions proportionately less but with standard head diameters.

SCREW SIZE	SCREW LENGTH EQUAL TO OR LESS THAN	SCREW SIZE	SCREW LENGTH EQUAL TO OR LESS THAN	SCREW SIZE	SCREW LENGTH EQUAL TO OR LESS THAN
0	⅛	6	3/16	⅜	9/16
1	⅛	8	¼	7/16	⅝
2	⅛	10	5/16	½	¾
3	⅛	12	⅜	9/16	13/16
4	3/16	¼	7/16	⅝	15/16
5	3/16	5/16	½	¾	1⅛



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 2a—*Cross-Recess Dimensions of Flat-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	0.090	0.079	0.058	0.012	
1	0.073	0.109	0.097	0.071	0.016	
2	0.086	0.129	0.117	0.084	0.019	
3	0.099	0.150	0.136	0.097	0.022	
4	0.112	0.169	0.155	0.110	0.026	
5	0.125	0.189	0.174	0.123	0.030	
6	0.138	0.209	0.193	0.136	0.033	
8	0.164	0.249	0.231	0.162	0.040	
10	0.190	0.289	0.269	0.188	0.047	Point same on all drivers
12	0.216	0.329	0.308	0.214	0.055	
¼	0.250	0.380	0.358	0.248	0.064	
5/16	0.3125	0.476	0.450	0.310	0.081	
⅜	0.375	0.572	0.542	0.372	0.098	
7/16	0.4375	0.609	0.578	0.397	0.105	
½	0.500	0.656	0.623	0.428	0.114	
9/16	0.5625	0.656	0.623	0.428	0.114	
⅝	0.625	0.656	0.623	0.428	0.114	
¾	0.750	0.656	0.623	0.428	0.114	

TABLE 2b—*Cross-Recess Dimensions of Flat-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	—	—	—	—	—	—
1	—	—	—	—	—	—
2	0.086	0.099	0.089	0.060	0.017	1
3	0.099	0.104	0.094	0.065	0.018	1
4	0.112	0.125	0.115	0.086	0.018	1
5	0.125	0.151	0.141	0.083	0.027	2
6	0.138	0.171	0.161	0.103	0.029	2
8	0.164	0.186	0.176	0.118	0.031	2
10	0.190	0.201	0.191	0.133	0.032	2
12	0.216	0.265	0.255	0.153	0.038	3
¼	0.250	0.280	0.270	0.168	0.039	3
5/16	0.3125	0.362	0.352	0.213	0.061	4
⅜	0.375	0.390	0.380	0.242	0.065	4
7/16	0.4375	0.406	0.396	0.258	0.068	4
½	0.500	0.421	0.411	0.273	0.069	4
9/16	0.5625	0.446	0.426	0.297	0.073	4
⅝	0.625	0.662	0.642	0.339	0.089	5
¾	0.750	0.745	0.725	0.403	0.100	5

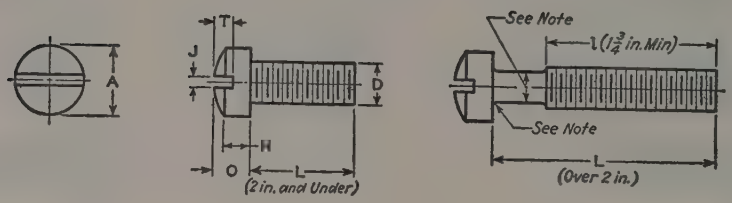
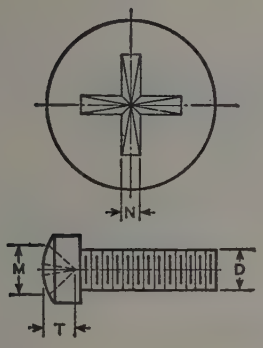


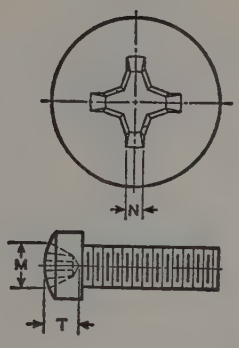
TABLE 3—*Dimensions of Fillister-Head Machine Screws*

NOMINAL SIZE	*D*	*A*		*H*		*O*		*J*		*T*	
	Max diameter of screw	Head diameter		Height of head		Total height of head		Width of slot		Depth of slot	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
0	0.060	0.096	0.083	0.045	0.037	0.059	0.043	0.023	0.016	0.025	0.015
1	0.073	0.118	0.104	0.053	0.045	0.071	0.055	0.026	0.019	0.031	0.020
2	0.086	0.140	0.124	0.062	0.053	0.083	0.066	0.031	0.023	0.037	0.025
3	0.099	0.161	0.145	0.070	0.061	0.095	0.077	0.035	0.027	0.043	0.030
4	0.112	0.183	0.166	0.079	0.069	0.107	0.088	0.039	0.031	0.048	0.035
5	0.125	0.205	0.187	0.088	0.078	0.120	0.100	0.043	0.035	0.054	0.040
6	0.138	0.226	0.208	0.096	0.086	0.132	0.111	0.048	0.039	0.060	0.045
8	0.164	0.270	0.250	0.113	0.102	0.156	0.133	0.054	0.045	0.071	0.054
10	0.190	0.313	0.292	0.130	0.118	0.180	0.156	0.060	0.050	0.083	0.064
12	0.216	0.357	0.334	0.148	0.134	0.205	0.178	0.067	0.056	0.094	0.074
¼	0.250	0.414	0.389	0.170	0.155	0.237	0.207	0.075	0.064	0.109	0.087
5/16	0.3125	0.518	0.490	0.211	0.194	0.295	0.262	0.084	0.072	0.137	0.110
⅜	0.375	0.622	0.590	0.253	0.233	0.355	0.315	0.094	0.081	0.164	0.133
7/16	0.4375	0.625	0.589	0.265	0.242	0.368	0.321	0.094	0.081	0.170	0.135
½	0.500	0.750	0.710	0.297	0.273	0.412	0.362	0.106	0.091	0.190	0.151
9/16	0.5625	0.812	0.768	0.336	0.308	0.466	0.410	0.118	0.102	0.214	0.172
⅝	0.625	0.875	0.827	0.375	0.345	0.521	0.461	0.133	0.116	0.240	0.193
¾	0.750	1.000	0.945	0.441	0.406	0.612	0.542	0.149	0.131	0.281	0.226

Note—Refer to Machine Screws—General Data.



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 3a—*Cross-Recess Dimensions of Fillister-Head Machine Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	0.072	0.062	0.047	0.008	
1	0.073	0.088	0.078	0.057	0.012	
2	0.086	0.105	0.093	0.069	0.014	
3	0.099	0.121	0.109	0.079	0.017	
4	0.112	0.137	0.124	0.089	0.020	
5	0.125	0.154	0.140	0.101	0.023	
6	0.138	0.169	0.156	0.110	0.026	
8	0.164	0.202	0.187	0.132	0.032	
10	0.190	0.235	0.219	0.153	0.038	Point same on all drivers
12	0.216	0.268	0.250	0.175	0.044	
1/4	0.250	0.310	0.292	0.202	0.052	
5/16	0.3125	0.388	0.367	0.253	0.065	
3/8	0.375	0.466	0.442	0.303	0.079	
7/16	0.4375	0.469	0.442	0.303	0.079	
1/2	0.500	0.562	0.532	0.366	0.096	
9/16	0.5625	0.609	0.576	0.397	0.105	
5/8	0.625	0.609	0.576	0.397	0.105	
3/4	0.750	0.609	0.576	0.397	0.105	

TABLE 3b—*Cross-Recess Dimensions of Fillister-Head Machine Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	—	—	—	—	—
1	0.073	—	—	—	—	—
2	0.086	0.103	0.093	0.076	0.018	1
3	0.099	0.113	0.103	0.087	0.018	1
4	0.112	0.125	0.115	0.099	0.018	1
5	0.125	0.158	0.148	0.109	0.028	2
6	0.138	0.169	0.159	0.121	0.029	2
8	0.164	0.191	0.181	0.144	0.032	2
10	0.190	0.213	0.203	0.167	0.034	2
12	0.216	0.271	0.261	0.191	0.039	3
1/4	0.250	0.299	0.289	0.220	0.042	3
5/16	0.3125	0.352	0.342	0.276	0.049	3
3/8	0.375	0.434	0.424	0.331	0.072	4
7/16	0.4375	0.443	0.433	0.334	0.074	4
1/2	0.500	0.449	0.439	0.339	0.074	4
9/16	0.5625	—	—	—	—	—
5/8	0.625	—	—	—	—	—
3/4	0.750	—	—	—	—	—

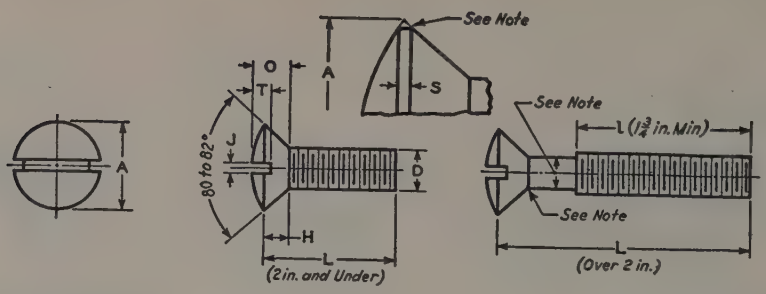


TABLE 4—*Dimensions of Oval-Head Machine Screws*

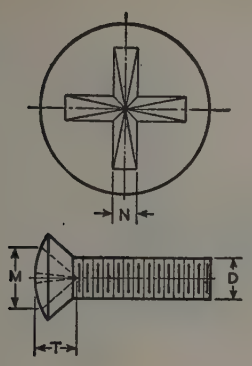
NOMINAL SIZE	D	A			S	H		O		J		T	
	Max diameter of screw	Head diameter			Flat on min screw	Height of head		Total height of head		Width of slot		Depth of slot	
		Max sharp	Min sharp	Absolute min with MILL S		Max	Min	Max	Min	Max	Min	Max	Min
0	0.060	0.119	0.105	0.101	0.002	0.035	0.026	0.056	0.041	0.023	0.016	0.030	0.025
1	0.073	0.146	0.130	0.126	0.003	0.043	0.033	0.068	0.052	0.026	0.019	0.038	0.031
2	0.086	0.172	0.156	0.150	0.003	0.051	0.040	0.080	0.063	0.031	0.023	0.045	0.037
3	0.099	0.199	0.181	0.175	0.004	0.059	0.048	0.092	0.073	0.035	0.027	0.052	0.043
4	0.112	0.225	0.207	0.200	0.004	0.067	0.055	0.104	0.084	0.039	0.031	0.059	0.049
5	0.125	0.252	0.232	0.225	0.005	0.075	0.062	0.116	0.095	0.043	0.035	0.067	0.055
6	0.138	0.279	0.257	0.249	0.005	0.083	0.069	0.128	0.105	0.048	0.039	0.074	0.060
8	0.164	0.332	0.308	0.300	0.006	0.100	0.084	0.152	0.126	0.054	0.045	0.088	0.072
10	0.190	0.385	0.359	0.348	0.007	0.116	0.098	0.176	0.148	0.060	0.050	0.103	0.084
12	0.216	0.438	0.410	0.397	0.008	0.132	0.112	0.200	0.169	0.067	0.056	0.117	0.096
¼	0.250	0.507	0.477	0.462	0.009	0.153	0.131	0.232	0.197	0.075	0.064	0.136	0.112
5/16	0.3125	0.635	0.600	0.581	0.011	0.191	0.165	0.290	0.249	0.084	0.072	0.171	0.141
⅜	0.375	0.762	0.722	0.700	0.013	0.230	0.200	0.347	0.300	0.094	0.081	0.206	0.170
7/16	0.4375	0.812	0.771	0.743	0.016	0.223	0.190	0.345	0.295	0.094	0.081	0.210	0.174
½	0.500	0.875	0.831	0.802	0.018	0.223	0.186	0.354	0.299	0.106	0.091	0.216	0.176
9/16	0.5625	1.000	0.950	0.919	0.020	0.260	0.220	0.410	0.350	0.118	0.102	0.250	0.207
⅝	0.625	1.125	1.069	1.035	0.023	0.298	0.253	0.467	0.399	0.133	0.116	0.285	0.235
¾	0.750	1.375	1.306	1.267	0.027	0.372	0.319	0.578	0.497	0.149	0.131	0.353	0.293

Note—Refer to Machine Screws—General Data.

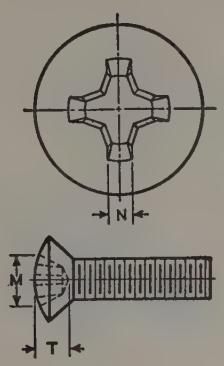
Edges of head may be rounded.

Short-length oval-head screws with a length equal to or less than the accompanying list have undercut heads, with the conical bearing surface approximately two thirds of the standard height, with slot depths and recess dimensions proportionately less but with standard head diameters.

SCREW SIZES	SCREW LENGTH EQUAL TO OR LESS THAN	SCREW SIZES	SCREW LENGTH EQUAL TO OR LESS THAN	SCREW SIZES	SCREW LENGTH EQUAL TO OR LESS THAN
0	⅛	6	3/16	⅜	9/16
1	⅛	8	¼	7/16	⅝
2	⅛	10	5/16	½	¾
3	⅛	12	⅜	9/16	13/16
4	3/16	¼	7/16	⅝	15/16
5	3/16	5/16	½	¾	1⅛



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 4a—*Cross-Recess Dimensions of Oval-Head Machine Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	0.090	0.079	0.058	0.012	
1	0.073	0.109	0.097	0.071	0.016	
2	0.086	0.129	0.117	0.084	0.019	
3	0.099	0.150	0.136	0.097	0.022	
4	0.112	0.169	0.155	0.110	0.026	
5	0.125	0.189	0.174	0.123	0.030	
6	0.138	0.209	0.193	0.136	0.033	
8	0.164	0.249	0.231	0.162	0.040	Point same on all drivers
10	0.190	0.289	0.269	0.188	0.047	
12	0.216	0.329	0.308	0.214	0.055	
1/4	0.250	0.380	0.358	0.248	0.064	
5/16	0.3125	0.476	0.450	0.310	0.081	
3/8	0.375	0.572	0.542	0.372	0.098	
7/16	0.4375	0.609	0.578	0.397	0.105	
1/2	0.500	0.656	0.623	0.428	0.114	
9/16	0.5625	0.656	0.623	0.428	0.114	
5/8	0.625	0.656	0.623	0.428	0.114	
3/4	0.750	0.656	0.623	0.428	0.114	

TABLE 4b—*Cross-Recess Dimensions of Oval-Head Machine Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	—	—	—	—	—
1	0.073	—	—	—	—	—
2	0.086	0.109	0.099	0.078	0.018	1
3	0.099	0.121	0.111	0.090	0.019	1
4	0.112	0.133	0.123	0.103	0.019	1
5	0.125	0.155	0.145	0.098	0.028	2
6	0.138	0.175	0.165	0.119	0.030	2
8	0.164	0.189	0.179	0.133	0.031	2
10	0.190	0.206	0.196	0.151	0.033	2
12	0.216	0.267	0.257	0.174	0.038	3
1/4	0.250	0.287	0.277	0.194	0.040	3
5/16	0.3125	0.387	0.377	0.266	0.065	4
3/8	0.375	0.407	0.397	0.285	0.068	4
7/16	0.4375	0.419	0.409	0.298	0.070	4
1/2	0.500	0.434	0.424	0.314	0.071	4
9/16	0.5625	0.464	0.444	0.342	0.075	4
5/8	0.625	0.656	0.636	0.387	0.089	5
3/4	0.750	0.741	0.721	0.452	0.098	5

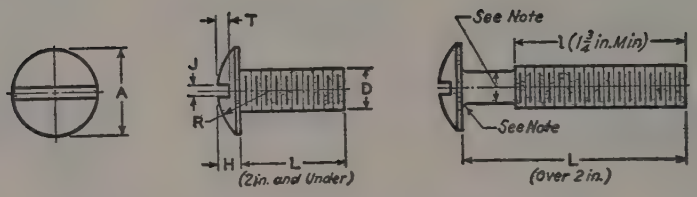
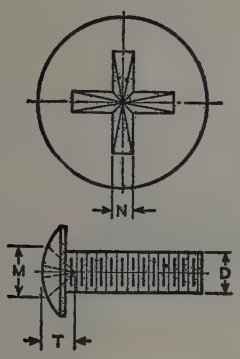


TABLE 5—*Dimensions of Truss-Head Machine Screws*

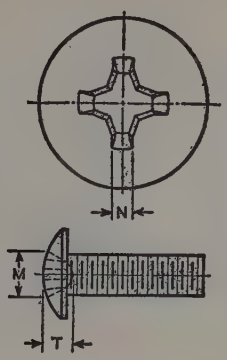
NOMINAL SIZE	*D*	*A*		*H*		*J*		*T*		*R*
	Max diameter of screw	Head diameter		Height of head		Width of slot		Depth of slot		Radius
		Max	Min	Max	Min	Max	Min	Max	Min	Max
2	0.086	0.194	0.180	0.053	0.044	0.031	0.023	0.031	0.022	0.129
3	0.099	0.226	0.211	0.061	0.051	0.035	0.027	0.036	0.026	0.151
4	0.112	0.257	0.241	0.069	0.059	0.039	0.031	0.040	0.030	0.169
5	0.125	0.289	0.272	0.078	0.066	0.043	0.035	0.045	0.034	0.191
6	0.138	0.321	0.303	0.086	0.074	0.048	0.039	0.050	0.037	0.211
7[a]	0.151	0.352	0.333	0.094	0.081	0.048	0.039	0.054	0.041	0.231
8	0.164	0.384	0.364	0.102	0.088	0.054	0.045	0.058	0.045	0.254
10	0.190	0.448	0.425	0.118	0.103	0.060	0.050	0.068	0.053	0.283
12	0.216	0.511	0.487	0.134	0.118	0.067	0.056	0.077	0.061	0.336
¼	0.250	0.573	0.546	0.150	0.133	0.075	0.064	0.087	0.070	0.375
5/16	0.3125	0.698	0.666	0.183	0.162	0.084	0.072	0.106	0.085	0.457
⅜	0.375	0.823	0.787	0.215	0.191	0.094	0.081	0.124	0.100	0.538
7/16	0.4375	0.948	0.907	0.248	0.221	0.094	0.081	0.142	0.116	0.619
½	0.500	1.073	1.028	0.280	0.250	0.106	0.091	0.161	0.131	0.701
9/16	0.5625	1.198	1.149	0.312	0.279	0.118	0.102	0.179	0.146	0.783
⅝	0.625	1.323	1.269	0.345	0.309	0.133	0.116	0.196	0.162	0.863
¾	0.750	1.573	1.511	0.410	0.368	0.149	0.131	0.234	0.182	1.024

[a] Dimensions of No. 7 size are included only for tapping screws.

Note—Refer to Machine Screws—General Data.



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 5a—*Cross-Recess Dimensions of Truss-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
2	0.086	0.109	0.101	0.071	0.016	
3	0.099	0.127	0.118	0.084	0.019	
4	0.112	0.144	0.135	0.194	0.022	
5	0.125	0.162	0.152	0.106	0.025	
6	0.138	0.183	0.173	0.119	0.029	
7[a]	0.151	0.198	0.186	0.129	0.031	
8	0.164	0.216	0.206	0.141	0.035	
10	0.190	0.251	0.239	0.164	0.042	Point
12	0.216	0.286	0.273	0.187	0.048	same
						on all
1/4	0.250	0.324	0.310	0.212	0.055	drivers
5/16	0.3125	0.391	0.373	0.255	0.067	
3/8	0.375	0.461	0.441	0.300	0.079	
7/16	0.4375	0.531	0.508	0.345	0.092	
1/2	0.500	0.601	0.576	0.391	0.105	
9/16	0.5625	0.671	0.643	0.437	0.118	
5/8	0.625	0.741	0.713	0.482	0.130	
3/4	0.750	0.881	0.847	0.574	0.154	

[a] Dimensions of No. 7 size are included only for tapping screws.

Table 5b—*Cross-Recess Dimensions of Truss-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
2	0.086	0.101	0.091	0.071	0.017	1
3	0.099	0.107	0.097	0.075	0.017	1
4	0.112	0.109	0.099	0.078	0.017	1
5	0.125	0.125	0.115	0.095	0.018	1
6	0.138	0.155	0.145	0.100	0.027	2
7[a]	0.151	0.162	0.152	0.107	0.028	2
8	0.164	0.170	0.160	0.115	0.029	2
10	0.190	0.185	0.175	0.131	0.030	2
12	0.216	0.245	0.235	0.155	0.035	3
1/4	0.250	0.260	0.250	0.170	0.036	3
5/16	0.3125	0.349	0.339	0.234	0.059	4
3/8	0.375	0.380	0.370	0.266	0.063	4
7/16	0.4375	0.411	0.401	0.297	0.068	4
1/2	0.500	0.419	0.409	0.308	0.069	4
9/16	0.5625	0.455	0.435	0.327	0.074	4
5/8	0.625	0.625	0.605	0.364	0.085	5
3/4	0.750	0.705	0.685	0.427	0.094	5

[a] Dimensions of No. 7 size are included only for tapping screws.

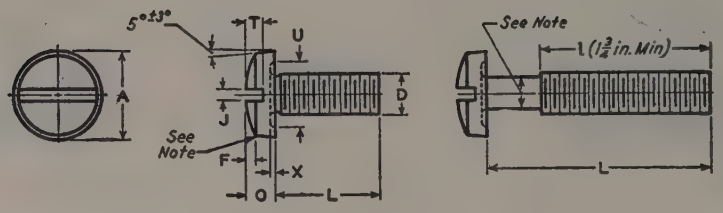


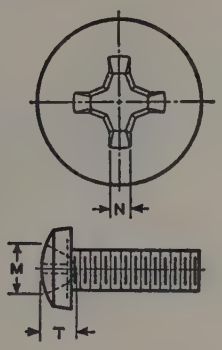
TABLE 6—*Dimensions of Binding-Head Machine Screws*

NOMINAL SIZE	*D*	*A*		*O*		*J*		*T*		*F*		*U*		*X*	
	Max diameter of screw	Head diameter		Total height of head		Width of slot		Depth of slot		Height of oval		Diameter of undercut[a]		Depth of undercut[a]	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
2	0.086	0.181	0.171	0.046	0.041	0.031	0.023	0.030	0.024	0.018	0.013	0.141	0.124	0.010	0.005
3	0.099	0.208	0.197	0.054	0.048	0.035	0.027	0.036	0.029	0.022	0.016	0.162	0.143	0.011	0.006
4	0.112	0.235	0.223	0.063	0.056	0.039	0.031	0.042	0.034	0.025	0.018	0.184	0.161	0.012	0.007
5	0.125	0.263	0.249	0.071	0.064	0.043	0.035	0.048	0.039	0.029	0.021	0.205	0.180	0.014	0.009
6	0.138	0.290	0.275	0.080	0.071	0.048	0.039	0.053	0.044	0.032	0.024	0.226	0.199	0.015	0.010
8	0.164	0.344	0.326	0.097	0.087	0.054	0.045	0.065	0.054	0.039	0.029	0.269	0.236	0.017	0.012
10	0.190	0.399	0.378	0.114	0.102	0.060	0.050	0.077	0.064	0.045	0.034	0.312	0.274	0.020	0.015
12	0.216	0.454	0.430	0.130	0.117	0.067	0.056	0.089	0.074	0.052	0.039	0.354	0.311	0.023	0.018
¼	0.250	0.513	0.488	0.153	0.138	0.075	0.064	0.105	0.088	0.061	0.046	0.410	0.360	0.026	0.021
5/16	0.3125	0.641	0.609	0.193	0.174	0.084	0.072	0.134	0.112	0.077	0.059	0.513	0.450	0.032	0.027
⅜	0.375	0.769	0.731	0.234	0.211	0.094	0.081	0.163	0.136	0.094	0.071	0.615	0.540	0.039	0.034

[a] The use of undercut is optional.

Note—Refer to Machine Screws—General Data.
Break sharp edge where spherical and conical surfaces meet.

This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

Table 6a—*Cross-Recess Dimensions of Binding-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
2	0.086	0.118	0.111	0.085	0.022	Point same on all drivers
3	0.099	0.135	0.128	0.098	0.025	
4	0.112	0.150	0.145	0.108	0.028	
5	0.125	0.171	0.162	0.123	0.031	
6	0.138	0.188	0.179	0.135	0.034	
8	0.164	0.224	0.212	0.163	0.089	
10	0.190	0.258	0.246	0.187	0.045	
12	0.216	0.295	0.279	0.213	0.051	
¼	0.250	0.333	0.317	0.240	0.058	
5/16	0.3125	0.417	0.396	0.302	0.073	
⅜	0.375	0.500	0.475	0.362	0.088	

TABLE 6b—*Cross-Recess Dimensions of Binding-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
2	0.086	0.097	0.087	0.063	0.017	1
3	0.099	0.107	0.097	0.073	0.017	1
4	0.112	0.115	0.105	0.081	0.017	1
5	0.125	0.145	0.135	0.085	0.018	2
6	0.138	0.157	0.147	0.098	0.026	2
8	0.164	0.183	0.173	0.125	0.028	2
10	0.190	0.202	0.192	0.145	0.029	2
12	0.216	0.264	0.254	0.169	0.032	3
¼	0.250	0.278	0.268	0.185	0.046	3
5/16	0.3125	0.347	0.337	0.221	0.068	4
⅜	0.375	0.397	0.387	0.271	0.076	4

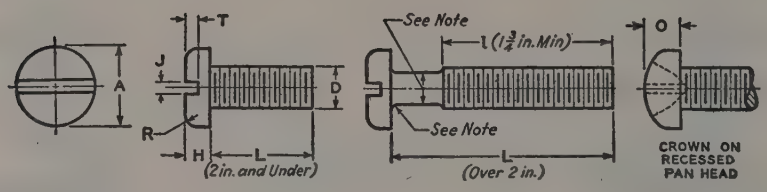
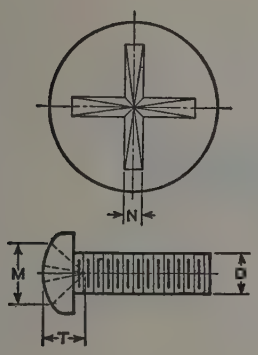


TABLE 7—*Dimensions of Pan-Head Machine Screws*

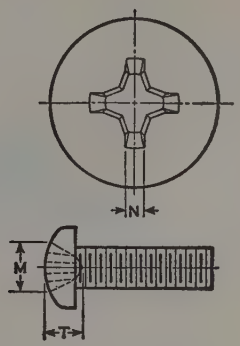
NOMINAL SIZE	*D*	*A*		*H*		*J*		*T*		*R*	*O*	
	Max diameter of screw	Head diameter		Height of head (slotted)		Width of slot		Depth of slot		Radius	Height of head (recessed)	
		Max	Min	Max	Min	Max	Min	Max	Min	Nominal	Max	Min
2	0.086	0.167	0.155	0.053	0.045	0.031	0.023	0.033	0.023	0.035	0.062	0.053
3	0.099	0.193	0.180	0.060	0.051	0.035	0.027	0.037	0.027	0.037	0.071	0.062
4	0.112	0.219	0.205	0.068	0.058	0.039	0.031	0.041	0.030	0.042	0.080	0.070
5	0.125	0.245	0.231	0.075	0.065	0.043	0.035	0.045	0.032	0.044	0.089	0.079
6	0.138	0.270	0.256	0.082	0.072	0.048	0.039	0.050	0.038	0.046	0.097	0.087
7[a]	0.151	0.296	0.281	0.089	0.079	0.048	0.039	0.055	0.040	0.049	0.106	0.096
8	0.164	0.322	0.306	0.096	0.085	0.054	0.045	0.058	0.043	0.052	0.115	0.105
10	0.190	0.373	0.357	0.110	0.099	0.060	0.050	0.067	0.050	0.061	0.133	0.122
12	0.216	0.425	0.407	0.125	0.112	0.067	0.056	0.077	0.060	0.078	0.151	0.139
¼	0.250	0.492	0.473	0.144	0.130	0.075	0.064	0.087	0.070	0.087	0.175	0.162
5/16	0.3125	0.615	0.594	0.178	0.162	0.084	0.072	0.109	0.092	0.099	0.218	0.203
⅜	0.375	0.740	0.716	0.212	0.195	0.094	0.081	0.130	0.113	0.143	0.261	0.244

[a] Dimensions of No. 7 size are included only for tapping screws.

Note—Refer to Machine Screws—General Data.



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 7a—*Cross-Recess Dimensions of Pan-Head Machine Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
2	0.086	0.109	0.101	0.071	0.018	
3	0.099	0.125	0.117	0.082	0.021	
4	0.112	0.142	0.133	0.093	0.024	
5	0.125	0.159	0.150	0.104	0.027	
6	0.138	0.176	0.166	0.115	0.030	Point
7[a]	0.151	0.192	0.183	0.125	0.033	same
8	0.164	0.209	0.199	0.136	0.036	on all
10	0.190	0.242	0.232	0.158	0.042	drivers
12	0.216	0.276	0.265	0.180	0.048	
1/4	0.250	0.320	0.307	0.209	0.056	
5/16	0.3125	0.400	0.386	0.260	0.071	
3/8	0.375	0.481	0.465	0.312	0.086	

[a] Dimensions of No. 7 size are included only for tapping screws.

TABLE 7b—*Cross-Recess Dimensions of Pan-Head Machine Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
2	0.086	0.101	0.091	0.071	0.017	1
3	0.099	0.109	0.099	0.080	0.018	1
4	0.112	0.119	0.109	0.090	0.018	1
5	0.125	0.155	0.145	0.103	0.028	2
6	0.138	0.163	0.153	0.111	0.028	2
7[a]	0.151	0.173	0.163	0.120	0.029	2
8	0.164	0.179	0.169	0.127	0.030	2
10	0.190	0.196	0.186	0.145	0.031	2
12	0.216	0.256	0.246	0.171	0.037	3
1/4	0.250	0.278	0.268	0.192	0.039	3
5/16	0.312	0.347	0.337	0.227	0.059	4
3/8	0.375	0.390	0.380	0.266	0.065	4

[a] Dimensions of No. 7 size are included only for tapping screws.

TABLE 8—*Dimensions for Hexagon-Head Machine Screws, Plain or Slotted*

NOMINAL SIZE	*D*, BASIC DIAMETER	STANDARD TRIMMED OR UPSET HEAD			OPTIONAL UPSET TYPE HEAD FOR SPECIAL REQUIREMENTS			*H*, HEIGHT OF HEAD		*J*, WIDTH OF SLOT		*T*, DEPTH OF SLOT	
		A		*W*	*A*		*W*						
		Head diameter		Across corners	Head diameter		Across corners						
		Max	Min	Min	Max	Min	Min	Max	Min	Max	Min	Max	Min
2	0.0860	0.125	0.120	0.134	—	—	—	0.050	0.040	—	—	—	—
3	0.0990	0.187	0.181	0.202	—	—	—	0.055	0.044	—	—	—	—
4	0.1120	0.187	0.181	0.202	0.219	0.213	0.238	0.060	0.049	0.039	0.031	0.036	0.025
5	0.1250	0.187	0.181	0.202	0.250	0.244	0.272	0.070	0.058	0.043	0.035	0.042	0.030
6	0.1380	0.250	0.244	0.272	—	—	—	0.080	0.067	0.048	0.039	0.046	0.033
8	0.1640	0.250	0.244	0.272	0.312	0.305	0.340	0.110	0.096	0.054	0.045	0.066	0.052
10	0.1900	0.312	0.305	0.340	—	—	—	0.120	0.105	0.060	0.050	0.072	0.057
12	0.2160	0.312	0.305	0.340	0.375	0.367	0.409	0.155	0.139	0.067	0.056	0.093	0.077
1/4	0.2500	0.375	0.367	0.409	0.437	0.428	0.477	0.190	0.172	0.075	0.064	0.101	0.083
5/16	0.3125	0.500	0.491	0.548	—	—	—	0.230	0.208	0.084	0.072	0.122	0.100
3/8	0.3750	0.562	0.552	0.616	—	—	—	0.295	0.270	0.094	0.081	0.156	0.131

Note—Refer to Machine Screws—General Data.

Bearing surface of head shall be at right angles to the axis of the screw within a tolerance of 2 deg and concentric with the axis of the body within a tolerance of 3% of the maximum width across flats.

Total head taper not to exceed 0.008 in.

Dimensions across flats and across corners of the head shall be measured at the greatest distance across the flats.

Hexagon-head machine screws are usually not slotted. The slot is optional.

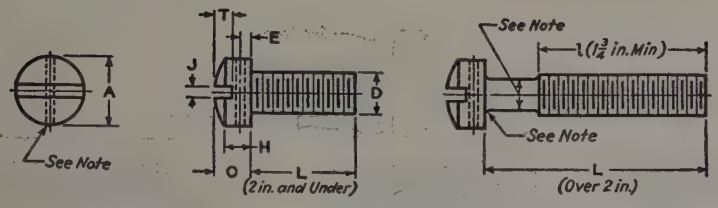


TABLE 9—*Dimensions of Fillister-Head Drilled Machine Screws*

NOMINAL SIZE	*D*	*A*		*H*		*O*		*J*		*T*		*E*	NOMINAL DRILL SIZE
	Max diameter of screw	Head diameter		Height of head		Total height of head		Width of slot		Depth of slot		Nonimal drill location	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min		
2	0.086	0.140	0.124	0.062	0.055	0.083	0.070	0.031	0.023	0.030	0.022	0.026	0.031
3	0.099	0.161	0.145	0.070	0.064	0.095	0.082	0.035	0.027	0.034	0.026	0.030	0.037
4	0.112	0.183	0.166	0.079	0.072	0.107	0.094	0.039	0.031	0.038	0.030	0.035	0.037
5	0.125	0.205	0.187	0.088	0.081	0.120	0.106	0.043	0.035	0.042	0.033	0.038	0.046
6	0.138	0.226	0.208	0.096	0.089	0.132	0.118	0.048	0.039	0.045	0.035	0.043	0.046
8	0.164	0.270	0.250	0.113	0.106	0.156	0.141	0.054	0.045	0.065	0.054	0.043	0.046
10	0.190	0.313	0.292	0.130	0.123	0.180	0.165	0.060	0.050	0.075	0.064	0.043	0.046
12	0.216	0.357	0.334	0.148	0.139	0.205	0.188	0.067	0.056	0.087	0.074	0.053	0.046
¼	0.250	0.414	0.389	0.170	0.161	0.237	0.219	0.075	0.064	0.102	0.087	0.062	0.062
5/16	0.3125	0.518	0.490	0.211	0.201	0.295	0.276	0.084	0.072	0.130	0.110	0.078	0.070
⅜	0.375	0.622	0.590	0.253	0.242	0.355	0.333	0.094	0.081	0.154	0.134	0.094	0.070

Note—Refer to Machine Screws—General Data.
Edges of the hole shall be free of burrs.

Drilled hole to be approximately at right angles to slot but must not break through slot.

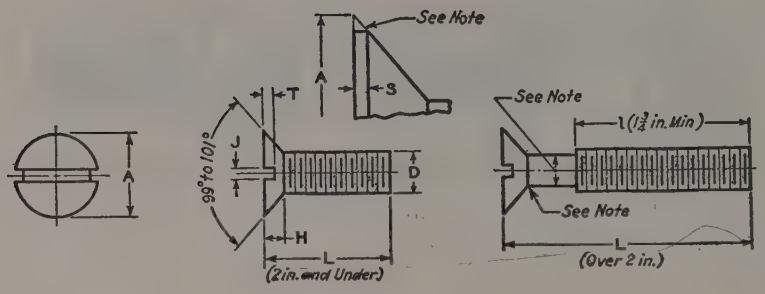
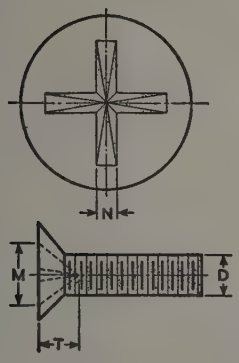


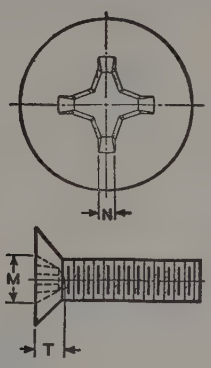
TABLE 10—*Dimensions of 100-Deg Flat-Head Machine Screws*

NOMINAL SIZE	*D*	*A*			*S*	*H*		*J*		*T*	
	Max diameter of screw	Head diameter			Flat on min screw	Height of head		Width of slot		Dept of slot	
		Max sharp	Min sharp	Absolute min with max *S*		Max	Min	Max	Min	Max	Min
4	0.112	0.225	0.207	0.200	0.003	0.048	0.040	0.039	0.031	0.024	0.017
6	0.138	0.279	0.257	0.249	0.004	0.060	0.051	0.048	0.039	0.030	0.022
8	0.164	0.332	0.308	0.300	0.004	0.072	0.062	0.054	0.045	0.036	0.027
10	0.190	0.385	0.359	0.348	0.005	0.083	0.072	0.060	0.050	0.042	0.031
¼	0.250	0.507	0.477	0.462	0.006	0.110	0.097	0.075	0.064	0.055	0.042
5/16	0.3125	0.635	0.600	0.581	0.008	0.138	0.123	0.084	0.072	0.069	0.053
⅜	0.375	0.762	0.722	0.700	0.009	0.165	0.148	0.094	0.081	0.083	0.064

Note—Refer to Machine Screws—General Data.
Edges of head may be rounded.



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



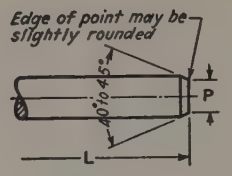
This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 10a—*Cross-Recess Dimensions of 100-Deg Flat-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
4	0.112	0.145	0.137	0.095	0.022	
6	0.138	0.185	0.174	0.121	0.029	
8	0.164	0.205	0.193	0.134	0.033	Point
10	0.190	0.244	0.231	0.159	0.040	same
						on all
¼	0.250	0.325	0.307	0.212	0.054	drivers
5/16	0.3125	0.406	0.382	0.264	0.068	
⅜	0.375	0.485	0.457	0.315	0.082	

TABLE 10b—*Cross-Recess Dimensions of 100-Deg Flat-Head Machine Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Max diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
4	0.112	0.114	0.104	0.075	0.017	1
6	0.138	0.151	0.141	0.083	0.024	2
8	0.164	0.166	0.156	0.098	0.024	2
10	0.190	0.181	0.171	0.113	0.024	2
¼	0.250	0.244	0.234	0.132	0.029	3
5/16	0.3125	0.314	0.304	0.165	0.042	4
⅜	0.375	0.339	0.329	0.190	0.042	4



CHAMFER OF BLANK BEFORE THREADING

TABLE 11—*Dimensions of Header Points for Machine Screws*

NOMINAL SIZE	THREADS PER INCH	P		L	NOMINAL SIZE	THREADS PER INCH	P		L
		Point diameter		Screw length			Point diameter		Screw length
		Max	Min	Max			Max	Min	Max
4	40	0.074	0.065	1/2	12	24	0.149	0.134	1 3/8
	48	0.079	0.070	1/2		28	0.156	0.141	1 3/8
5	40	0.086	0.076	1/2	1/4	20	0.170	0.153	1 1/2
	44	0.088	0.079	1/2		28	0.187	0.169	1 1/2
6	32	0.090	0.080	3/4	5/16	18	0.221	0.200	1 1/2
	40	0.098	0.087	3/4		24	0.237	0.215	1 1/2
8	32	0.114	0.102	1	3/8	16	0.270	0.244	1 1/2
	36	0.118	0.106	1		24	0.295	0.267	1 1/2
10	24	0.125	0.112	1 1/4	7/16	14	0.316	0.287	1 1/2
	32	0.138	0.124	1 1/4		20	0.342	0.310	1 1/2
					1/2	13	0.367	0.333	1 1/2
						20	0.399	0.362	1 1/2

Capscrews—General Data (Tables 12, 13, and 14)

Bearing Surface—The bearing surface of capscrew heads, except flat heads, shall be within 2 deg of the right angles to the body.

Eccentricity—The heads of round- and fillister-head capscrews shall not be eccentric with the body beyond a tolerance of 3% of the maximum head diameter. The heads of flat-head capscrews shall not be eccentric with the body beyond a tolerance of 0.010 in. total runout, or 1% of the diameter of the head, whichever is the greater.

Depth of Slots—The depth of slots is measured from the highest part of the head to the intersection of the bottom of the slot with the head surface.

Length of Capscrews—The length of capscrews shall be measured from the largest diameter of the bearing surface of the head to the extreme point, in a line parallel to the axis of the screw.

Tolerance in Length—The length of capscrews shall not vary from that specified by more than the following: up to 1 in. in length, minus 1/32 in.; over 1 in. to 2 in. inclusive, minus 1/16 in.; over 2 in., minus 3/32 in.

Length of Thread—The minimum length of thread on capscrews shall be equal to 2 *D* plus 1/4 in. A tolerance of plus 2 1/2 pitch minus 0 will be allowed. When capscrews are too short for the specified minimum thread length, the complete threads shall extend to within 2 1/2 threads of the head.

Points—Capscrews shall have a chamfer point. The included angle of the threaded point shall be approximately 90 deg. The

diameter of the point shall be: maximum 91.5% of basic minor diameter, plus 0.001 in.; and minimum 83.5% of basic minor diameter, minus 0.001 in.

Thread Series and Tolerances—The threads on capscrews shall be either the American National Coarse (NC-3) or the American National Fine-Thread Series (NF-3).

Finish—Slotted-head capscrew heads shall be machined. Slotted-head capscrews are usually not heat-treated.

All table dimensions are in inches.

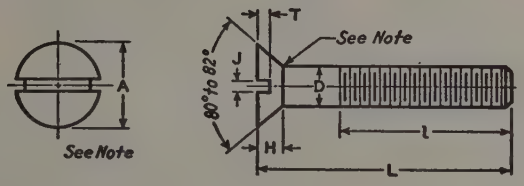


TABLE 12—*Dimensions of Flat-Head Capscrews*

NOMINAL SIZE	*D* Body diameter		*A* Head diameter		*H* Height of head	*J* Width of slot		*T* Depth of slot	
	Max	Min	Max	Min	Average	Max	Min	Max	Min
¼	0.250	0.245	0.500	0.477	0.140	0.075	0.064	0.069	0.046
5/16	0.3125	0.307	0.625	0.598	0.176	0.084	0.072	0.086	0.057
⅜	0.375	0.369	0.750	0.720	0.210	0.094	0.081	0.103	0.069
7/16	0.4375	0.431	0.8125	0.780	0.210	0.094	0.081	0.103	0.069
½	0.500	0.493	0.875	0.841	0.210	0.106	0.091	0.103	0.069
9/16	0.5625	0.555	1.000	0.962	0.245	0.118	0.102	0.120	0.080
⅝	0.625	0.617	1.125	1.083	0.281	0.133	0.116	0.137	0.092
¾	0.750	0.742	1.375	1.326	0.352	0.149	0.131	0.171	0.115
⅞	0.875	0.866	1.625	1.568	0.423	0.167	0.147	0.206	0.139
1	1.000	0.990	1.875	1.811	0.494	0.188	0.166	0.240	0.162

Note—Refer to Capscrews—General Data.

The maximum and minimum head diameters, *A*, are extended to the theoretical sharp corners.

The radius of the fillet at the base of the head shall not exceed twice the pitch of the screw thread.

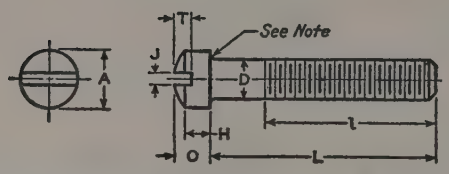


TABLE 13—*Dimensions of Fillister-Head Capscrews*

NOMINAL SIZE	*D*		*A*		*H*		*O*		*J*		*T*	
	Body diameter		Head diameter		Height of head		Total height of head		Width of slot		Depth of slot	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
¼	0.250	0.245	0.375	0.363	0.172	0.157	0.216	0.195	0.075	0.064	0.097	0.077
5/16	0.3125	0.307	0.437	0.424	0.203	0.186	0.253	0.230	0.084	0.072	0.115	0.090
⅜	0.375	0.369	0.562	0.547	0.250	0.229	0.314	0.285	0.094	0.081	0.143	0.113
7/16	0.4375	0.431	0.625	0.608	0.297	0.274	0.368	0.337	0.094	0.081	0.168	0.133
½	0.500	0.493	0.750	0.731	0.328	0.301	0.412	0.376	0.106	0.091	0.188	0.148
9/16	0.5625	0.555	0.812	0.792	0.375	0.347	0.466	0.428	0.118	0.102	0.214	0.169
⅝	0.625	0.617	0.875	0.853	0.422	0.392	0.521	0.480	0.133	0.116	0.240	0.190
¾	0.750	0.742	1.000	0.976	0.500	0.466	0.612	0.566	0.149	0.131	0.283	0.233
⅞	0.875	0.866	1.125	1.098	0.594	0.556	0.720	0.669	0.167	0.147	0.334	0.264
1	1.000	0.990	1.312	1.282	0.656	0.613	0.802	0.744	0.188	0.166	0.372	0.292

Note—Refer to Capscrews—General Data.

The radius of the fillet at the base of the head:

for sizes ¼ to ⅜ in. inclusive is 0.016 minimum and 0.031 maximum.

7/16 to 9/16 in. inclusive is 0.016 minimum and 0.047 maximum.

⅝ to 1 in. inclusive is 0.031 minimum and 0.062 maximum.

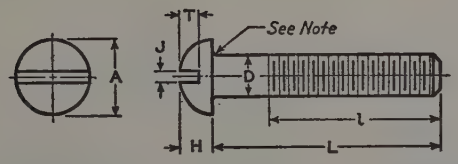


TABLE 14—*Dimensions of Round-Head Capscrews*

NOMINAL SIZE	*D*		*A*		*H*		*J*		*T*	
	Body diameter		Head diameter		Height of head		Width of slot		Dept of slot	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1/4	0.250	0.245	0.437	0.418	0.191	0.175	0.075	0.064	0.117	0.097
5/16	0.3125	0.307	0.562	0.541	0.246	0.226	0.084	0.072	0.151	0.126
3/8	0.375	0.369	0.625	0.602	0.273	0.252	0.094	0.081	0.168	0.138
7/16	0.4375	0.431	0.750	0.725	0.328	0.302	0.094	0.081	0.202	0.167
1/2	0.500	0.493	0.812	0.786	0.355	0.328	0.106	0.091	0.219	0.179
9/16	0.5625	0.555	0.937	0.908	0.410	0.379	0.118	0.102	0.253	0.208
5/8	0.625	0.617	1.000	0.970	0.438	0.405	0.133	0.116	0.270	0.220
3/4	0.750	0.742	1.250	1.215	0.547	0.506	0.149	0.131	0.337	0.277

Note—Refer to Capscrews—General Data.

Radius of the fillet at the base of the head:

for sizes 1/4 to 3/8 in. inclusive is 0.016 minimum and 0.031 maximum.

7/16 to 9/16 in. inclusive is 0.016 minimum to 0.047 maximum.

5/8 to 1 in. inclusive is 0.031 minimum and 0.062 maximum.

Wood Screws—General Data (Tables 15 through 17b)

Radius of Fillet Under Head—The fillet under the head for wood screws shall have a nominal radius of 1/64 in. for sizes through No. 9, and 1/32 in. for sizes larger than No. 9.

Depth of Slot—The depth of slots is measured from the highest part of the head to the intersection of the bottom of the slot with the head surface.

Length of Wood Screws—The length of wood screws shall be measured from the largest diameter of the bearing surface of the head to the extreme point in a line parallel to the axis.

Tolerance in Length—The tolerance in length of wood screws shall be plus 0 and minus 1/32 in. on lengths of 1/4 in. to 5/8 in inclusive; plus 0 and minus 3/64 in. on lengths 3/4 in. to 1 1/2 in.; plus 0 and minus 1/16 in. on lengths 1 1/2 to 2 3/4 in. inclusive; and plus 0 and minus 3/32 in. on lengths 3 in. to 5 in. inclusive.

Length of Thread—The length of the thread of wood screws shall be equal to approximately two thirds of the length of the screw.

Points—Wood screws shall be furnished with gimlet points.

Finish—Wood screws are regularly furnished with naturally bright finish and are not heat-treated.

All table dimensions are in inches.

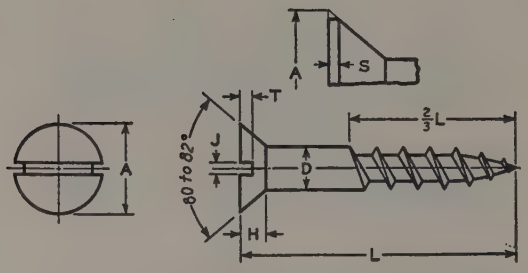


TABLE 15—*Dimensions of Flat-Head Wood Screws*

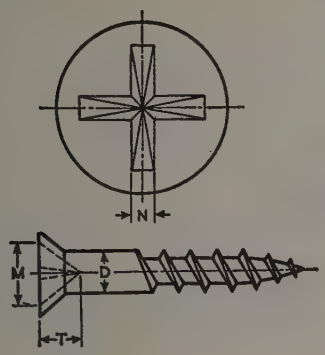
NOMINAL SIZE	*D*	*A*			*S*	*H*		*J*		*T*		NUMBER THREADS PER INCH
	Basic diameter of screw	Head diameter			Flat on min screw	Height of head		Width of slot		Depth of slot		
		Max sharp	Min sharp	Absolute min with max *S*		Max	Min	Max	Min	Max	Min	
0	0.060	0.119	0.105	0.101	0.002	0.035	0.026	0.023	0.016	0.015	0.010	32
1	0.073	0.146	0.130	0.126	0.003	0.043	0.033	0.026	0.019	0.019	0.012	28
2	0.086	0.172	0.156	0.150	0.003	0.051	0.040	0.031	0.023	0.023	0.015	26
3	0.099	0.199	0.181	0.175	0.004	0.059	0.048	0.035	0.027	0.027	0.017	24
4	0.112	0.225	0.207	0.200	0.004	0.067	0.055	0.039	0.031	0.030	0.020	22
5	0.125	0.252	0.232	0.225	0.005	0.075	0.062	0.043	0.035	0.034	0.022	20
6	0.138	0.279	0.257	0.249	0.005	0.083	0.069	0.048	0.039	0.038	0.024	18
7	0.151	0.305	0.283	0.274	0.005	0.091	0.076	0.048	0.039	0.041	0.027	16
8	0.164	0.332	0.308	0.300	0.006	0.100	0.084	0.054	0.045	0.045	0.029	15
9	0.177	0.358	0.334	0.323	0.006	0.108	0.091	0.054	0.045	0.049	0.032	14
10	0.190	0.385	0.359	0.348	0.007	0.116	0.098	0.060	0.050	0.053	0.034	13
12	0.216	0.438	0.410	0.397	0.008	0.132	0.112	0.067	0.056	0.060	0.039	11
14	0.242	0.491	0.461	0.447	0.009	0.148	0.127	0.075	0.064	0.068	0.044	10
16	0.268	0.544	0.512	0.496	0.010	0.164	0.141	0.075	0.064	0.075	0.049	9
18	0.294	0.597	0.563	0.545	0.011	0.180	0.155	0.084	0.072	0.083	0.054	8
20	0.320	0.650	0.614	0.595	0.012	0.196	0.170	0.084	0.072	0.090	0.059	8
24	0.372	0.756	0.716	0.693	0.013	0.228	0.198	0.094	0.081	0.105	0.069	7

Note—Refer to Wood Screws—General Data.

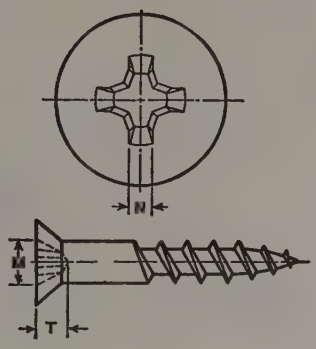
Maximum permissible variation in number of threads per inch is plus or minus 10%.

Tolerance on diameter, *D*, equals +0.004 to −0.007 in.

Edges of head may be rounded.



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 15a—*Cross-Recess Dimensions of Flat-Head Wood Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Basic diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	0.090	0.079	0.058	0.012	
1	0.073	0.109	0.097	0.071	0.016	
2	0.086	0.129	0.117	0.084	0.019	
3	0.099	0.149	0.136	0.097	0.022	
4	0.112	0.169	0.155	0.110	0.026	
5	0.125	0.189	0.174	0.123	0.030	
6	0.138	0.209	0.193	0.136	0.033	
7	0.151	0.229	0.212	0.149	0.037	Point same
8	0.164	0.249	0.231	0.162	0.040	on all
9	0.177	0.269	0.250	0.176	0.043	drivers
10	0.190	0.289	0.270	0.188	0.047	
12	0.216	0.328	0.308	0.214	0.055	
14	0.242	0.368	0.346	0.240	0.062	
16	0.268	0.408	0.384	0.265	0.069	
18	0.294	0.448	0.423	0.291	0.077	
20	0.320	0.488	0.460	0.317	0.083	
24	0.372	0.568	0.537	0.370	0.097	

TABLE 15b—*Cross-Recess Dimensions of Flat-Head Wood Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Basic diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	—	—	—	—	—
1	0.073	—	—	—	—	—
2	0.086	0.099	0.089	0.060	0.017	1
3	0.099	0.104	0.094	0.065	0.018	1
4	0.112	0.125	0.115	0.086	0.018	1
5	0.125	0.151	0.141	0.083	0.027	2
6	0.138	0.171	0.161	0.103	0.029	2
7	0.151	0.186	0.176	0.118	0.031	2
8	0.164	0.201	0.191	0.133	0.033	2
9	0.177	0.211	0.201	0.143	0.033	2
10	0.190	0.255	0.245	0.143	0.037	3
12	0.216	0.280	0.270	0.168	0.040	3
14	0.242	0.300	0.290	0.188	0.042	3
16	0.268	0.324	0.314	0.213	0.045	3
18	0.294	0.375	0.365	0.227	0.063	4
20	0.320	0.390	0.380	0.242	0.065	4
24	0.372	0.421	0.411	0.273	0.070	4

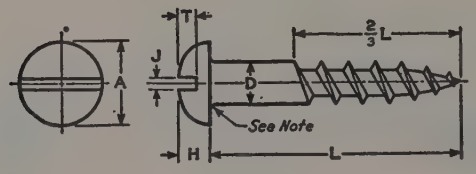


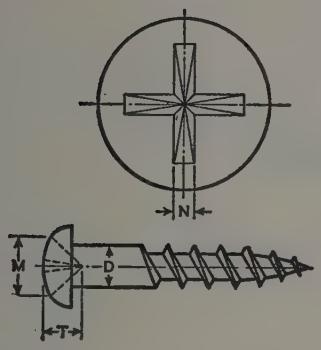
TABLE 16—*Dimensions of Round-Head Wood Screws*

NOMINAL SIZE	*D*	*A*		*H*		*J*		*T*		NUMBER THREADS PER INCH
	Basic diameter of screw	Head diameter		Height of head		Width of slot		Depth of slot		
		Max	Min	Max	Min	Max	Min	Max	Min	
0	0.060	0.113	0.099	0.053	0.043	0.023	0.016	0.039	0.029	32
1	0.073	0.138	0.122	0.061	0.051	0.026	0.019	0.044	0.033	28
2	0.086	0.162	0.146	0.069	0.059	0.031	0.023	0.048	0.037	26
3	0.099	0.187	0.169	0.078	0.067	0.035	0.027	0.053	0.040	24
4	0.112	0.211	0.193	0.086	0.075	0.039	0.031	0.058	0.044	22
5	0.125	0.236	0.217	0.095	0.083	0.043	0.036	0.063	0.047	20
6	0.138	0.260	0.240	0.103	0.091	0.048	0.039	0.068	0.051	18
7	0.151	0.285	0.264	0.111	0.099	0.048	0.039	0.072	0.055	16
8	0.164	0.309	0.287	0.120	0.107	0.054	0.045	0.077	0.058	15
9	0.177	0.334	0.311	0.128	0.115	0.054	0.045	0.082	0.062	14
10	0.190	0.359	0.334	0.137	0.123	0.060	0.050	0.087	0.065	13
12	0.216	0.408	0.382	0.153	0.139	0.067	0.056	0.096	0.073	11
14	0.242	0.457	0.429	0.170	0.155	0.075	0.064	0.106	0.080	10
16	0.268	0.506	0.476	0.187	0.171	0.075	0.064	0.115	0.087	9
18	0.294	0.555	0.523	0.204	0.187	0.084	0.072	0.125	0.094	8
20	0.320	0.604	0.570	0.220	0.203	0.084	0.072	0.134	0.101	8
24	0.372	0.702	0.664	0.254	0.235	0.094	0.081	0.154	0.116	7

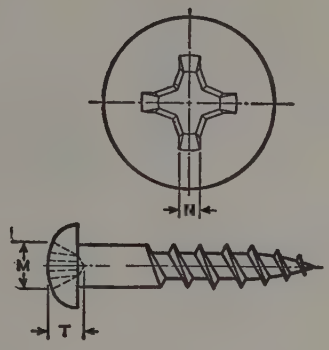
Note—Refer to Wood Screws—General Data.

Maximum permissible variation in number of threads per inch is plus or minus 10%.

Tolerance on diameter, *D*, equals +0.004 to −0.007 in.



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 16a—*Cross-Recess Dimensions of Round-Head Wood Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Basic diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	0.085	0.074	0.054	0.011	
1	0.073	0.103	0.092	0.067	0.015	
2	0.086	0.122	0.109	0.079	0.018	
3	0.099	0.140	0.127	0.091	0.021	
4	0.112	0.158	0.145	0.103	0.024	
5	0.125	0.177	0.163	0.115	0.027	
6	0.138	0.195	0.180	0.127	0.031	
7	0.151	0.214	0.198	0.139	0.034	Point same
8	0.164	0.232	0.215	0.151	0.037	on all
9	0.177	0.250	0.234	0.163	0.041	drivers
10	0.190	0.270	0.250	0.176	0.044	
12	0.216	0.306	0.286	0.200	0.051	
14	0.242	0.343	0.322	0.224	0.057	
16	0.268	0.380	0.357	0.248	0.064	
18	0.294	0.416	0.392	0.270	0.070	
20	0.320	0.453	0.427	0.294	0.077	
24	0.372	0.527	0.498	0.342	0.090	

TABLE 16b—*Cross-Recess Dimensions of Round-Head Wood Screws*

NOMINAL SIZE	D	M		T	N	DRIVER SIZE
	Basic diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	—	—	—	—	—
1	0.073	—	—	—	—	—
2	0.086	0.111	0.101	0.089	0.018	1
3	0.099	0.119	0.109	0.097	0.019	1
4	0.112	0.127	0.117	0.105	0.018	1
5	0.125	0.151	0.141	0.104	0.027	2
6	0.138	0.159	0.149	0.112	0.027	2
7	0.151	0.167	0.157	0.120	0.029	2
8	0.164	0.175	0.165	0.128	0.030	2
9	0.177	0.183	0.173	0.137	0.030	2
10	0.190	0.192	0.182	0.145	0.031	2
12	0.216	0.246	0.236	0.165	0.036	3
14	0.242	0.262	0.252	0.182	0.037	3
16	0.268	0.278	0.268	0.198	0.039	3
18	0.294	0.336	0.326	0.231	0.057	4
20	0.320	0.353	0.343	0.248	0.059	4
24	0.372	0.384	0.374	0.281	0.064	4

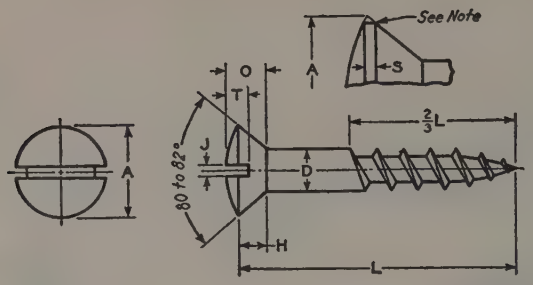
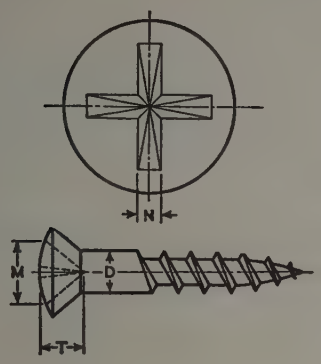


TABLE 17—*Dimensions of Oval-Head Wood Screws*

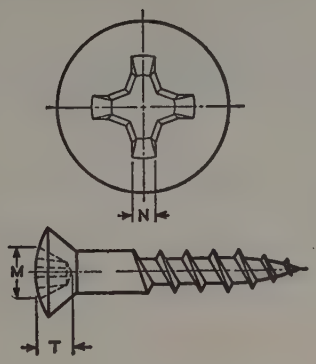
NOMINAL SIZE	*D*	*A*			*S*	*H*		*O*		*J*		*T*		NUMBER THREADS PER INCH
	Basic diameter of screw	Head diameter			Flat on min screw	Height of head		Total height of head		Width of slot		Depth of slot		
		Max sharp	Min sharp	Absolute min with max *S*		Max	Min	Max	Min	Max	Min	Max	Min	
0	0.060	0.119	0.105	0.101	0.002	0.035	0.026	0.056	0.041	0.023	0.016	0.030	0.025	32
1	0.073	0.146	0.130	0.126	0.003	0.043	0.033	0.068	0.052	0.026	0.019	0.038	0.031	28
2	0.086	0.172	0.156	0.150	0.003	0.051	0.040	0.080	0.063	0.031	0.023	0.045	0.037	26
3	0.099	0.199	0.181	0.175	0.004	0.059	0.048	0.092	0.073	0.035	0.027	0.052	0.043	24
4	0.112	0.225	0.207	0.200	0.004	0.067	0.055	0.104	0.084	0.039	0.031	0.059	0.049	22
5	0.125	0.252	0.232	0.225	0.005	0.075	0.062	0.116	0.095	0.043	0.035	0.067	0.055	20
6	0.138	0.279	0.257	0.249	0.005	0.083	0.069	0.128	0.105	0.048	0.039	0.074	0.060	18
7	0.151	0.305	0.283	0.274	0.005	0.091	0.076	0.140	0.116	0.048	0.039	0.081	0.066	16
8	0.164	0.332	0.308	0.300	0.006	0.100	0.084	0.152	0.126	0.054	0.045	0.088	0.072	15
9	0.177	0.358	0.334	0.323	0.006	0.108	0.091	0.164	0.137	0.054	0.045	0.095	0.078	14
10	0.190	0.385	0.359	0.348	0.007	0.116	0.098	0.176	0.148	0.060	0.050	0.103	0.084	13
12	0.216	0.438	0.410	0.397	0.008	0.132	0.112	0.200	0.169	0.067	0.056	0.117	0.096	11
14	0.242	0.491	0.461	0.447	0.009	0.148	0.127	0.224	0.190	0.075	0.064	0.132	0.108	10
16	0.268	0.544	0.512	0.496	0.010	0.164	0.141	0.248	0.212	0.075	0.064	0.146	0.120	9
18	0.294	0.597	0.563	0.545	0.011	0.180	0.155	0.272	0.233	0.084	0.072	0.160	0.132	8
20	0.320	0.650	0.614	0.595	0.012	0.196	0.170	0.296	0.254	0.084	0.072	0.175	0.144	8
24	0.372	0.756	0.716	0.693	0.013	0.228	0.198	0.344	0.297	0.094	0.081	0.204	0.168	7

Note—Refer to Wood Screws—General Data.
Tolerance on diameter, *D*, equals +0.004 to −0.007 in.

Maximum permissible variation in number of threads per inch is plus or minus 10%.
Edges of head may be rounded.



This type of recess consists of two intersecting slots with parallel sides converging to a sharp apex at bottom of recess.



This type of recess has a large center opening, tapered wings, and blunt bottom, with all edges relieved or rounded.

TABLE 17a—*Cross-Recess Dimensions of Oval-Head Wood Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Basic diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	0.090	0.079	0.058	0.012	
1	0.073	0.109	0.097	0.071	0.016	
2	0.086	0.129	0.117	0.084	0.019	
3	0.099	0.149	0.136	0.097	0.022	
4	0.112	0.169	0.155	0.110	0.026	
5	0.125	0.189	0.174	0.123	0.030	
6	0.138	0.209	0.193	0.136	0.033	
7	0.151	0.229	0.212	0.149	0.037	Point same on all drivers
8	0.164	0.249	0.231	0.162	0.040	
9	0.177	0.269	0.250	0.176	0.043	
10	0.190	0.289	0.270	0.188	0.047	
12	0.216	0.328	0.308	0.214	0.055	
14	0.242	0.368	0.346	0.240	0.062	
16	0.268	0.408	0.384	0.265	0.069	
18	0.294	0.448	0.423	0.291	0.077	
20	0.320	0.488	0.460	0.317	0.083	
24	0.372	0.568	0.537	0.370	0.097	

TABLE 17b—*Cross-Recess Dimensions of Oval-Head Wood Screws*

NOMINAL SIZE	*D*	*M*		*T*	*N*	DRIVER SIZE
	Basic diameter of screw	Diameter of recess		Depth of recess	Width of recess	
		Max	Min	Max	Min	
0	0.060	—	—	—	—	—
1	0.073	—	—	—	—	—
2	0.086	0.109	0.099	0.078	0.018	1
3	0.099	0.121	0.111	0.090	0.019	1
4	0.112	0.133	0.123	0.103	0.019	1
5	0.125	0.155	0.145	0.098	0.028	2
6	0.138	0.175	0.165	0.119	0.030	2
7	0.151	0.186	0.176	0.131	0.031	2
8	0.164	0.202	0.192	0.148	0.033	2
9	0.177	0.213	0.203	0.159	0.034	2
10	0.190	0.258	0.248	0.166	0.037	3
12	0.216	0.280	0.270	0.189	0.040	3
14	0.242	0.302	0.292	0.213	0.042	3
16	0.268	0.329	0.319	0.241	0.046	3
18	0.294	0.378	0.368	0.258	0.064	4
20	0.320	0.397	0.387	0.277	0.066	4
24	0.372	0.433	0.423	0.314	0.072	4

Tapping Screws—General Data (Tables 1, 2, 4, 5, 7, and 15 through 21)

Bearing Surface—The bearing surface of tapping-screw heads, except flat and oval heads shall be at right angles to the body within 2 deg.

Eccentricity—Tapping-screw heads shall not be eccentric with the body beyond a tolerance of 3% of the maximum head diameter.

Depth of Slots—The depth of slots is measured from the highest part of the head to the intersection of the bottom of the slot with the head surface.

Length of Tapping Screws—Length of tapping screws shall be measured from the largest diameter of the bearing surface of the head to the extreme point in a line parallel to the axis of the screw.

Tolerance in Length—The tolerance in length of Type A tapping screws shall be plus $\frac{1}{32}$ in. and minus $\frac{1}{32}$ in. on lengths up to 1 in. inclusive; on longer lengths plus $\frac{3}{64}$ in. and minus $\frac{3}{64}$ in. For Type B and C tapping screws, the tolerance in length shall be plus 0 and minus $\frac{1}{32}$ in. on lengths from $\frac{1}{4}$ in. to $\frac{5}{8}$ in. inclusive; plus 0 and minus $\frac{3}{64}$ in. on lengths $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. inclusive; and plus 0 and minus $\frac{1}{16}$ in. on lengths over $1\frac{1}{2}$ in.

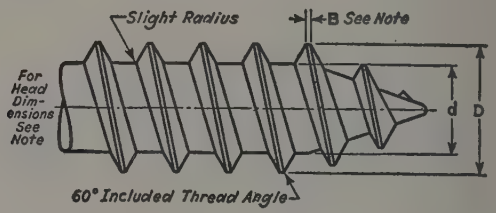
Length of Thread—All types of tapping screws are threaded to the head.

Finish—Tapping screws are regularly furnished case hardened.

All table dimensions are in inches.

TABLE 18—*Dimensions of Tapping Screws, Type A*

NOMINAL SIZE	THREADS PER INCH	D		d	
		Major diameter		Minor diameter	
		Max	Min	Max	Min
0	40	0.060	0.057	0.042	0.039
1	32	0.075	0.072	0.051	0.048
2	32	0.088	0.084	0.061	0.056
3	28	0.101	0.097	0.076	0.071
4	24	0.114	0.110	0.083	0.078
5	20	0.130	0.126	0.095	0.090
6	18	0.141	0.136	0.102	0.096
7	16	0.158	0.152	0.114	0.108
8	15	0.168	0.162	0.123	0.116
10	12	0.194	0.188	0.133	0.126
12	11	0.221	0.215	0.162	0.155
14	10	0.254	0.248	0.185	0.178
16	10	0.280	0.274	0.197	0.189
18	9	0.306	0.300	0.217	0.209
20	9	0.333	0.327	0.234	0.226
24	9	0.390	0.383	0.291	0.282



Note—Refer to Tapping Screws—General Data.

For head dimensions, except hexagon heads, refer to table of contents for location of proper tables.

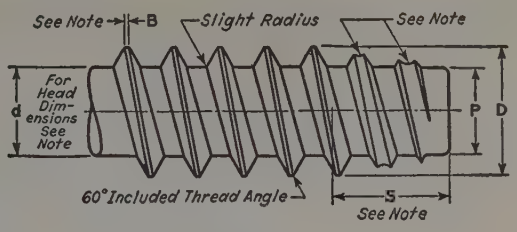
Maximum crest of thread, *B*, up to and including size No. 8 equals 0.004 in.; maximum crest of thread over size No. 8 equals 0.006 in.

A reasonable bluntness or truncation of the point as shown on the illustration will be permissible.

(*Continued on next page.*)

TABLE 19—*Dimensions of Tapping Screws, Type B*

NOMINAL SIZE	THREADS PER INCH	*D* Major diameter		*d* Minor diameter		*P* Point diameter	
		Max	Min	Max	Min	Max	Min
0	48	0.060	0.057	0.036	0.033	0.033	0.031
1	42	0.075	0.072	0.049	0.046	0.046	0.044
2	32	0.088	0.084	0.064	0.060	0.055	0.052
3	28	0.101	0.097	0.075	0.071	0.069	0.066
4	24	0.114	0.110	0.086	0.082	0.078	0.075
5	20	0.130	0.126	0.094	0.090	0.084	0.081
6	20	0.139	0.135	0.104	0.099	0.093	0.090
7	19	0.154	0.149	0.115	0.109	0.101	0.098
8	18	0.166	0.161	0.122	0.116	0.107	0.104
10	16	0.189	0.183	0.141	0.135	0.130	0.127
12	14	0.215	0.209	0.164	0.157	0.146	0.143
¼	14	0.246	0.240	0.192	0.185	0.174	0.170
5/16	12	0.315	0.308	0.244	0.236	0.235	0.231
⅜	12	0.380	0.371	0.309	0.299	0.298	0.294
7/16	10	0.440	0.431	0.359	0.349	0.348	0.344
½	10	0.504	0.495	0.423	0.413	0.411	0.407



Note—Refer to Tapping Screws—General Data.

For head dimensions, except hexagon heads, refer to table of contents for location of proper tables.

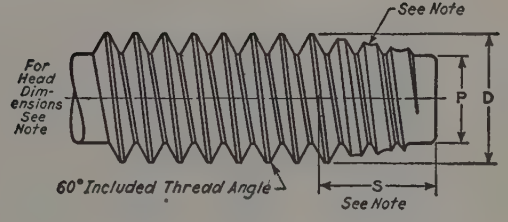
Maximum crest of thread, *B*, up to and including size No. 8 equals 0.004 in.; maximum crest of thread over size No. 8 equals 0.006 in.

Tapered threads have unfinished crests.

Taper length, *S*, is 2 to 2½ times the pitch of the thread.

TABLE 20—*Dimensions of Tapping Screws, Type C*

NOMINAL SIZE	THREADS PER INCH	*D* Major diameter	*P* Point diameter	
		Max	Max	Min
4	40	0.1120	0.086	0.077
4	48	0.1120	0.090	0.083
5	40	0.1250	0.099	0.090
5	44	0.1250	0.101	0.093
6	32	0.1380	0.106	0.095
6	40	0.1380	0.112	0.103
8	32	0.1640	0.132	0.121
8	36	0.1640	0.135	0.125
10	24	0.1900	0.147	0.133
10	32	0.1900	0.158	0.147
12	24	0.2160	0.173	0.159
12	28	0.2160	0.179	0.167
¼	20	0.2500	0.198	0.181
¼	28	0.2500	0.213	0.201
5/16	18	0.3125	0.255	0.236
5/16	24	0.3125	0.269	0.255
⅜	16	0.3750	0.310	0.289
⅜	24	0.3750	0.332	0.318



Note—Refer to Tapping Screws—General Data.

For head dimensions, except hexagon heads, refer to table of contents for location of proper tables.

Tapered threads have unfinished crests.

Screws having a length of 8 pitches or less will have a taper length, *S*, of 2½ to 3½ times the pitch distance. Longer lengths will have a taper length, *S*, of 3½ to 4½ times the pitch distance.

Point-diameter maximum is the basic minor diameter plus 20% of the double thread depth. The point-diameter minimum is the basic minor diameter less the Class 2 pitch-diameter tolerance.

Major diameters of complete threads conform to NC-2 and NF-2 tolerances.

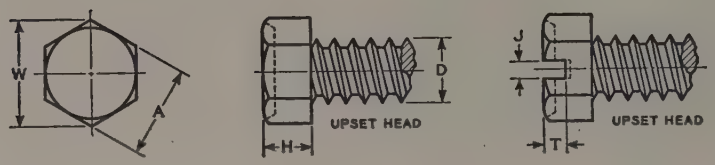


TABLE 21—*Dimensions of Hexagon-Head Tapping Screws, Plain and Slotted*

NOMINAL SIZE	*D*	*A*		*W*	*H*		*J*		*T*	
	Body diameter of screw	Width across flats		Width across corners	Height of head		Width of slot		Depth of slot	
		Max	Min	Min	Max	Min	Max	Min	Max	Min
1	0.073	0.125	0.120	0.134	0.050	0.040	—	—	—	—
2	0.086	0.125	0.120	0.134	0.050	0.040	—	—	—	—
3	0.099	0.187	0.181	0.202	0.055	0.044	—	—	—	—
4	0.112	0.187	0.181	0.202	0.060	0.049	0.039	0.031	0.036	0.025
5	0.125	0.187	0.181	0.202	0.070	0.058	0.043	0.035	0.042	0.030
6	0.138	0.250	0.244	0.272	0.080	0.067	0.048	0.039	0.046	0.033
7	0.151	0.250	0.244	0.272	0.090	0.076	0.048	0.039	0.054	0.040
8	0.164	0.250	0.244	0.272	0.110	0.096	0.054	0.045	0.066	0.052
10	0.190	0.312	0.305	0.340	0.120	0.105	0.060	0.050	0.072	0.057
12	0.216	0.312	0.305	0.340	0.155	0.139	0.067	0.056	0.093	0.077
14	0.242	0.375	0.367	0.409	0.190	0.172	0.075	0.064	0.101	0.083
1/4	0.250	0.375	0.367	0.409	0.190	0.172	0.075	0.064	0.101	0.083
5/16	0.3125	0.500	0.491	0.548	0.230	0.208	0.084	0.072	0.122	0.100
3/8	0.375	0.562	0.552	0.616	0.295	0.270	0.094	0.081	0.156	0.131

Note—Refer to Tapping Screws—General Data.

Bearing surface of head shall be at right angles to the axis of the screw within a tolerance of 2 deg and concentric with the axis of the body within a tolerance of 3% of the maximum width across flats.

Total head taper not to exceed 0.008 in.

Dimensions across flats and across corners of the head shall be measured at the greatest distance across the flats.

Hexagon head tapping screws are usually not slotted. The slot is optional.

Slotted Headless Setscrews—General Data (Table 22)

Length—The length of headless setscrews shall be the overall length.

Tolerance in Length—The length of slotted headless setscrews shall not vary from that specified by more than the following: up to 1 in. in length, minus 1/32 in.; over 1 in. to 2 in. inclusive, minus 1/16 in.; over 2 in., minus 3/32 in.

Length of Thread—Slotted headless setscrews shall be threaded the entire length.

Thread Series and Tolerances—The screw threads on slotted headless setscrews shall be either American National Coarse (NC-2) of the American National Fine-Thread Series (NF-2), unless otherwise specified.

Finish—Slotted headless setscrews shall be regularly furnished case hardened.

Eccentricity of Dog Points—The allowable eccentricity of dog-point axis on slotted headless setscrews with respect to axis of screw shall not exceed 3% of nominal diameter of screw with a minimum of 0.005 in.

All table dimensions are in inches.

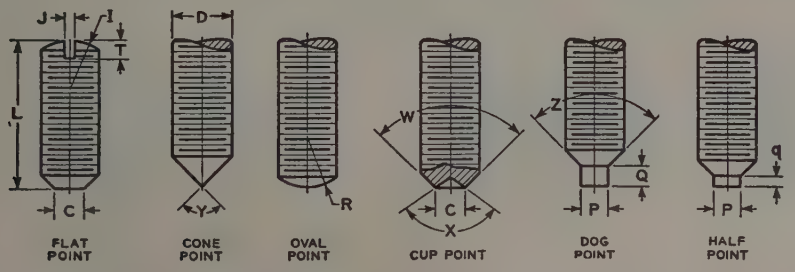


TABLE 22—*Dimensions of Slotted Headless Setscrews*

NOMINAL SIZE	D	R	I	J	T	C		P		Q	q
	Body diameter of screw	Radius of oval-point screw	Radius of slotted headless end	Width of slot	Depth of slot	Diameter of cup and flat points		Diameter of dog point		Height of dog	
						Max	Min	Max	Min	Full	Half
5	0.125	0.094	0.125	0.023	0.031	0.067	0.057	0.083	0.078	0.060	0.030
6	0.138	0.109	0.138	0.025	0.035	0.074	0.064	0.092	0.087	0.070	0.035
8	0.164	0.125	0.164	0.029	0.041	0.087	0.076	0.109	0.103	0.080	0.040
10	0.190	0.141	0.190	0.032	0.048	0.102	0.088	0.127	0.120	0.090	0.045
12	0.216	0.156	0.216	0.036	0.054	0.115	0.101	0.144	0.137	0.110	0.055
1/4	0.250	0.188	0.250	0.045	0.063	0.132	0.118	0.156	0.149	0.125	0.063
5/16	0.3125	0.234	0.313	0.051	0.078	0.172	0.156	0.203	0.195	0.156	0.078
3/8	0.375	0.281	0.375	0.064	0.094	0.212	0.194	0.250	0.241	0.188	0.094
7/16	0.4375	0.328	0.438	0.072	0.109	0.252	0.232	0.297	0.287	0.219	0.109
1/2	0.500	0.375	0.500	0.081	0.125	0.291	0.270	0.344	0.334	0.250	0.125
9/16	0.5625	0.422	0.563	0.091	0.141	0.332	0.309	0.391	0.379	0.281	0.140
5/8	0.625	0.469	0.625	0.102	0.156	0.371	0.347	0.469	0.456	0.313	0.156
3/4	0.750	0.563	0.750	0.129	0.188	0.450	0.425	0.563	0.549	0.375	0.188

Note—Refer to Slotted Headless Setscrews—General Data.

Where usable length of thread is less than the nominal diameter, half dog point shall be used.

When L equals nominal diameter or less, $Y = 118 \pm 2$ deg; when L exceeds nominal diameter, $Y = 90 \pm 2$ deg.

Point angles: $W = 80$ deg to 90 deg; $X = 118 \pm 5$ deg; $Z = 100$ deg to 110 deg.

Socket-Head Capscrews and Setscrews

SAE Standard

Report of Screw Threads Technical Committee approved October 1947. This SAE Standard conforms with American Standard Socket Head Cap Screws and Socket Set Screws, ASA B18.3—1947.

Socket-Head Capscrews—Reference Notes (Table 1)

Body Diameter, D, refers to the unthreaded portion of the screw, and the maximum diameter is the basic diameter or size of the screw. Threads shall conform to American Standard Screw Threads, ASA B1.1.

Concentricity of head, body, and thread shall permit acceptance when checked with a compound G gage which will gage the maximum diameters of these three parts simultaneously. This gage shall have the head and body diameters at their maximum values (*D* and *A*, Table 1) but expressed to four decimal places, and the pitch diameter at the maximum value allowed for Class 3, NC and Class 3, NF, American Standard Screw Threads, ASA B1.1.

Head Chamfer, E—The head shall be flat and chamfered. The

TABLE 1—*Dimensions of Fluted and Hexagon Socket-Head Capscrews*[a]

SCREW SIZE			FLUTED AND HEXAGON HEADS							HEXAGON HEAD		FLUTED HEAD					
D			*A*		*H*		*S*			*J*		*J*		*M*		*N*	
Body diameter			Head diameter		Head height		Head side-height			Socket width across flats		Socket diameter minor		Socket diameter major		Width of socket land	
Nom	Max	Min	Max	Min	Max	Min	Nom	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
2	0.0860	0.0840	0.140	0.136	0.086	0.083	0.0788	0.0803	0.0773	0.0635	1/16	0.064	0.063	0.074	0.073	0.016	0.015
3	0.0990	0.0968	0.161	0.157	0.099	0.096	0.0907	0.0923	0.0891	0.0791	5/64	0.082	0.080	0.098	0.097	0.022	0.021
4	0.1120	0.1096	0.183	0.178	0.112	0.109	0.1026	0.1043	0.1009	0.0791	5/64	0.082	0.080	0.098	0.097	0.022	0.021
5	0.1250	0.1226	0.205	0.200	0.125	0.122	0.1146	0.1163	0.1129	0.0947	3/32	0.098	0.096	0.115	0.113	0.025	0.023
6	0.1380	0.1353	0.226	0.221	0.138	0.134	0.1265	0.1284	0.1246	0.0947	3/32	0.098	0.096	0.115	0.113	0.025	0.023
8	0.1640	0.1613	0.270	0.265	0.164	0.160	0.1503	0.1522	0.1484	0.1270	1/8	0.128	0.126	0.149	0.147	0.032	0.030
10	0.1900	0.1867	5/16	0.306	0.190	0.185	0.1741	0.1765	0.1717	0.1582	5/32	0.163	0.161	0.188	0.186	0.039	0.037
12	0.2160	0.2127	11/32	0.337	0.216	0.211	0.1980	0.2005	0.1957	0.1582	5/32	0.163	0.161	0.188	0.186	0.039	0.037
1/4	0.2500	0.2464	3/8	0.367	1/4	0.244	0.2291	0.2317	0.2265	0.1895	3/16	0.190	0.188	0.221	0.219	0.050	0.048
5/16	0.3125	0.3084	7/16	0.429	5/16	0.306	0.2864	0.2894	0.2834	0.2207	7/32	0.221	0.219	0.256	0.254	0.060	0.058
3/8	0.3750	0.3705	9/16	0.553	3/8	0.368	0.3437	0.3469	0.3405	0.3155	5/16	0.319	0.316	0.380	0.377	0.092	0.089
7/16	0.4375	0.4326	5/8	0.615	7/16	0.430	0.4010	0.4046	0.3974	0.3155	5/16	0.319	0.316	0.380	0.377	0.092	0.089
1/2	0.5000	0.4948	3/4	0.739	1/2	0.492	0.4583	0.4620	0.4546	0.3780	3/8	0.386	0.383	0.463	0.460	0.112	0.109
9/16	0.5625	0.5569	13/16	0.801	9/16	0.554	0.5156	0.5196	0.5116	0.3780	3/8	0.386	0.383	0.463	0.460	0.112	0.109
5/8	0.6250	0.6191	7/8	0.863	5/8	0.616	0.5729	0.5771	0.5687	0.5030	1/2	0.509	0.506	0.604	0.601	0.138	0.134
3/4	0.7500	0.7436	1	0.987	3/4	0.741	0.6875	0.6920	0.6830	0.5655	9/16	0.535	0.531	0.631	0.627	0.149	0.145
7/8	0.8750	0.8680	1 1/8	1.111	7/8	0.865	0.8020	0.8069	0.7971	0.5655	9/16	0.604	0.600	0.709	0.705	0.168	0.164
1	1.0000	0.9924	1 5/16	1.297	1	0.989	0.9166	0.9220	0.9112	0.6290	5/8	0.685	0.681	0.801	0.797	0.189	0.185
1 1/8	1.1250	1.1165	1 1/2	1.483	1 1/8	1.113	1.0312	1.0372	1.0254	0.7540	3/4	0.828	0.824	0.970	0.966	0.231	0.227
1 1/4	1.2500	1.2415	1 3/4	1.733	1 1/4	1.238	1.1457	1.1516	1.1398	0.7540	3/4	0.828	0.824	0.970	0.966	0.231	0.227
1 3/8	1.3750	1.3649	1 7/8	1.855	1 3/8	1.361	1.2604	1.2675	1.2533	0.7540	3/4	0.828	0.824	0.970	0.966	0.231	0.227
1 1/2	1.5000	1.4899	2	1.979	1 1/2	1.485	1.3750	1.3821	1.3679	1.0040	1	1.007	1.003	1.275	1.271	0.298	0.294

[a] In all sizes, the number of flutes is six.
All dimensions are in inches.

flat shall be normal to the axis of the screw and the chamfer, *E*, shall be at an angle of 30 ± 2 deg with the surface of the flat. The edge between flat and chamfer shall be slightly rounded.

Socket Depth, T—Maximum socket depth, *T*, should not exceed three fourths of minimum head height, *H*.

Length Under Head, L—The length of the screw shall be measured, on a line parallel to the axis, from the plane of the bearing surface under the head to the plane of the flat of the point. The difference between consecutive lengths shall be as follows:

1. for screw lengths ¼ to 1 in., difference = ⅛ in.
2. for screw lengths 1 to 4 in., difference = ¼ in.
3. for screw lengths 4 to 6 in., difference = ½ in.

Length Tolerance—The allowable tolerance on the length, *L*, under the head on lengths 2 in. and under shall be 3% of the nominal length with a minimum of 0.030, two thirds to be applied plus and one third minus; on lengths over 2 in. to 6 in., plus or

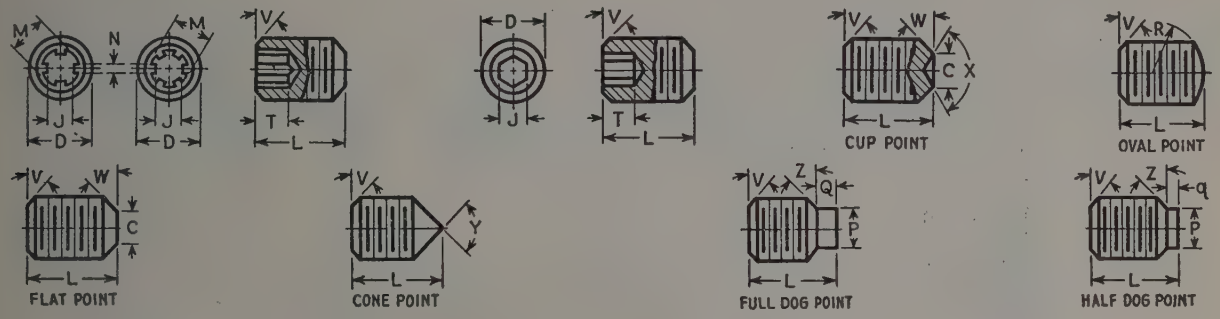


TABLE 2—*Dimensions of Fluted and Hexagon Socket Headless Setscrews*[a]

SCREW SIZE	FLUTED AND HEXAGON SOCKET TYPES									HEXAGON TYPE		FLUTED TYPE					
D	*C*			*R*	*Y*		*P*		*Q*	*q*	*J*		*J*		*M*		*N*	
Nominal diameter	Cup- and flat-point diameter			Oval-point radius	Cone-point angle		Dog point				Socket width across flats		Socket diameter minor		Socket diameter major		Socket land width	
					118 ± 2 deg for these lengths and under	90 ± 2 deg for these lengths and over	Diameter		Full	Half								
	Mean	Max	Min				Max	Min			Max	Min	Max	Min	Max	Min	Max	Min
5	1/16	0.067	0.057	3/32	1/8	3/16	0.083	0.078	0.06	0.03	0.0635	1/16	0.053	0.052	0.071	0.070	0.022	0.021
6	0.069	0.074	0.064	7/64	1/8	3/16	0.092	0.087	0.07	0.03	0.0635	1/16	0.056	0.055	0.079	0.078	0.023	0.022
8	5/64	0.087	0.076	1/8	3/16	1/4	0.109	0.103	0.08	0.04	0.0791	5/64	0.082	0.080	0.098	0.097	0.022	0.021
10	3/32	0.102	0.088	9/64	3/16	1/4	0.127	0.120	0.09	0.04	0.0947	3/32	0.098	0.096	0.115	0.113	0.025	0.023
12	7/64	0.115	0.101	5/32	3/16	1/4	0.144	0.137	0.11	0.06	0.0947	3/32	0.098	0.096	0.115	0.113	0.025	0.023
1/4	1/8	0.132	0.118	3/16	1/4	5/16	5/32	0.149	1/8	1/16	0.1270	1/8	0.128	0.126	0.149	0.147	0.032	0.030
5/16	11/64	0.172	0.156	15/64	5/16	3/8	13/64	0.195	5/32	5/64	0.1582	5/32	0.163	0.161	0.188	0.186	0.039	0.037
3/8	13/64	0.212	0.194	9/32	3/8	7/16	1/4	0.241	3/16	3/32	0.1895	3/16	0.190	0.188	0.221	0.219	0.050	0.048
7/16	15/64	0.252	0.232	21/64	7/16	1/2	19/64	0.287	7/32	7/64	0.2207	7/32	0.221	0.219	0.256	0.254	0.060	0.058
1/2	9/32	0.291	0.270	3/8	1/2	9/16	11/32	0.334	1/4	1/8	0.2520	1/4	0.254	0.252	0.298	0.296	0.068	0.066
9/16	5/16	0.332	0.309	27/64	9/16	5/8	25/64	0.379	9/32	9/64	0.2520	1/4	0.254	0.252	0.298	0.296	0.068	0.066
5/8	23/64	0.371	0.347	15/32	5/8	3/4	15/32	0.456	5/16	5/32	0.3155	5/16	0.319	0.316	0.380	0.377	0.092	0.089
3/4	7/16	0.450	0.425	9/16	3/4	7/8	9/16	0.549	3/8	3/16	0.3780	3/8	0.386	0.383	0.463	0.460	0.112	0.109
7/8	33/64	0.530	0.502	21/32	7/8	1	21/32	0.642	7/16	7/32	0.5030	1/2	0.509	0.506	0.604	0.601	0.138	0.134
1	19/32	0.609	0.579	3/4	1	1 1/8	3/4	0.734	1/2	1/4	0.5655	9/16	0.535	0.531	0.631	0.627	0.149	0.145
1 1/8	43/64	0.689	0.655	27/32	1 1/8	1 1/4	27/32	0.826	9/16	9/32	0.5655	9/16	0.604	0.600	0.709	0.705	0.168	0.164
1 1/4	3/4	0.767	0.733	15/16	1 1/4	1 1/2	15/16	0.920	5/8	5/16	0.6290	5/8	0.685	0.681	0.801	0.797	0.189	0.185
1 3/8	53/64	0.848	0.808	1 1/32	1 3/8	1 5/8	1 1/32	1.011	11/16	1 1/32	0.6290	5/8	0.744	0.740	0.869	0.865	0.207	0.203
1 1/2	29/32	0.926	0.886	1 1/8	1 1/2	1 3/4	1 1/8	1.105	3/4	3/8	0.7540	3/4	0.828	0.824	0.970	0.966	0.231	0.227
1 3/4	1 1/16	1.086	1.039	1 5/16	1 3/4	2	1 5/16	1.289	7/8	7/16	1.0040	1	1.007	1.003	1.275	1.271	0.298	0.294
2	1 7/32	1.244	1.193	1 1/2	2	2 1/4	1 1/2	1.474	1	1/2	1.0040	1	1.007	1.003	1.275	1.271	0.298	0.294

[a] The number of flutes for Nos. 5 and 6 is four. The number of flutes for No. 8 and larger is six.
All dimensions are in inches.

minus 1/32 in.; and on lengths over 6 in., plus or minus 1/16 in.

Thread Length, l—The length of the thread is measured from the extreme point to the last usable thread and shall be as follows:

National Coarse:
- $l = 2D + \frac{1}{2}$ in. (where this length of thread would be greater than half the screw length)
- $l = \frac{1}{2} L$ (where this length of thread would be greater than $2D + \frac{1}{2}$ in.)

National Fine:
- $l = 1\frac{1}{2} D + \frac{1}{2}$ in. (where this length of thread would be greater than three eighths the screw length)
- $l = \frac{3}{8} L$ (where this length of thread would be greater than $1\frac{1}{2}D + \frac{1}{2}$ in.)

Screws too short to allow application of these formulas shall be threaded as close to the head as practicable.

Screw Point Chamfer, Z—The point shall be flat and chamfered. The flat shall be normal to the axis of the screw and the

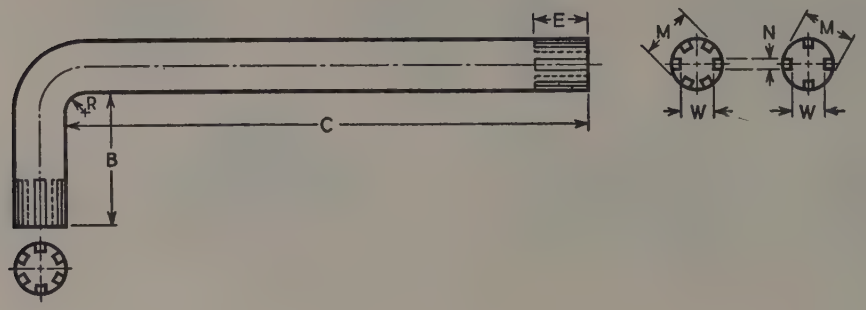


TABLE 3—*Dimensions of Keys for Fluted Socket-Head Capscrews and Setscrews*[a]

D		M		W		N		E	B		C				R
Screw size		Major diameter		Minor diameter		Width of flute		Length of flute	Length short arm		Length long arm				Radius of bend
											Short series		Long series		
Cap	Set	Max	Min	Max	Min	Max	Min	Min	Max	Min	Max	Min	Max	Min	
—	5	0.0690	0.0680	0.0510	0.0500	0.0260	0.0250	1/8	21/32	15/32	1 27/32	1 21/32	—	—	1/16
—	6	0.0760	0.0750	0.0530	0.0520	0.0280	0.0270	1/8	21/32	15/32	1 27/32	1 21/32	—	—	1/16
2	5, 6	0.0720	0.0710	0.0600	0.0590	0.0190	0.0180	1/8	21/32	15/32	1 27/32	2 21/32	—	—	1/16
3, 4	8	0.0940	0.0930	0.0780	0.0765	0.0260	0.0250	1/8	45/64	33/64	1 31/32	1 25/32	—	—	5/64
5, 6	10	0.1100	0.1090	0.0940	0.0925	0.0290	0.0280	5/32	3/4	9/16	2 3/32	1 29/32	—	—	3/32
5, 6	12	0.1100	0.1090	0.0940	0.0925	0.0290	0.0280	5/32	3/4	9/16	2 3/32	1 29/32	—	—	3/32
8	1/4	0.1440	0.1425	0.1230	0.1215	0.0370	0.0355	3/16	27/32	21/32	2 11/32	2 5/32	3 27/32	3 21/32	1/8
10, 12	5/16	0.1830	0.1815	0.1580	0.1565	0.0440	0.0425	7/32	15/16	3/4	2 19/32	2 13/32	4 7/32	4 1/32	5/32
1/4	3/8	0.2160	0.2145	0.1720	0.1705	0.0550	0.0535	1/4	1 1/32	27/32	2 27/32	2 21/32	4 19/32	4 13/32	3/16
5/16	7/16	0.2510	0.2495	0.2010	0.1995	0.0655	0.0640	9/32	1 1/8	15/16	3 3/32	2 29/32	4 31/32	4 25/32	7/32
—	1/2	0.2910	0.2895	0.2390	0.2375	0.0775	0.0760	1 1/32	1 7/32	1 1/32	3 11/32	3 5/32	5 11/32	5 5/32	1/4
—	9/16	0.2910	0.2895	0.2390	0.2375	0.0775	0.0760	1 1/32	1 7/32	1 1/32	3 11/32	3 5/32	5 11/32	5 5/32	1/4
3/8, 7/16	5/8	0.3720	0.3705	0.3100	0.3085	0.0975	0.0960	3/8	1 13/32	1 5/32	3 27/32	3 21/32	6 3/32	5 29/32	5/16
1/2, 9/16	3/4	0.4540	0.4525	0.3770	0.3755	0.1185	0.1170	7/16	1 15/32	1 9/32	4 11/32	4 5/32	6 27/32	6 21/32	3/8
5/8	7/8	0.5950	0.5935	0.5000	0.4975	0.1460	0.1445	1/2	1 23/32	1 17/32	5 11/32	5 5/32	8 11/32	8 5/32	1/2
3/4	1	0.6200	0.6175	0.5240	0.5215	0.1615	0.1590	9/16	1 27/32	1 21/32	5 27/32	5 21/32	9 3/32	8 29/32	1/2
7/8	1 1/8	0.6980	0.6955	0.5930	0.5905	0.1805	0.1780	5/8	1 27/32	1 21/32	5 27/32	5 21/32	9 3/32	8 29/32	9/16
1	1 1/4	0.7900	0.7875	0.6740	0.6715	0.1975	0.1950	1 1/16	1 31/32	1 25/32	6 11/32	6 5/32	9 27/32	9 21/32	5/8
—	1 3/8	0.8580	0.8555	0.7330	0.7305	0.2155	0.2130	3/4	2 3/32	1 15/16	6 27/32	6 21/32	10 19/32	10 13/32	11/16
1 1/8, 1 1/4, 1 3/8	1 1/2	0.9590	0.9565	0.8170	0.8145	0.2395	0.2370	13/16	2 7/32	2 1/32	7 11/32	7 5/32	11 11/32	11 5/32	3/4
—	1 3/4	1.2640	1.2615	0.9960	0.9935	0.3065	0.3040	15/16	2 23/32	2 17/32	9 11/32	9 5/32	14 11/32	14 5/32	7/8
1 1/2	2	1.2640	1.2615	0.9960	0.9935	0.3065	0.3040	1 1/16	2 23/32	2 17/32	9 11/32	9 5/32	14 11/32	14 5/32	1

[a] The number of flutes for Nos. 5 and 6 is four. The number of flutes for No. 8 and larger is six.
All dimensions are in inches.

chamfer, Z, shall be at an angle of 35 + 5 deg, −0 deg with the plane of the flat. The chamfer shall extend to the bottom of the thread, and edge between flat and chamfer shall be slightly rounded.

Socket Setscrews—Reference Notes (Table 2)

Usable Length of Thread—Where usable length of thread is less than nominal diameter, half dog point shall be used.

Allowable eccentricity of dog-point axis with respect to the screw axis shall not exceed 3% of the nominal diameter of the screw with a maximum of 0.005 in.

Chamfers and Point Angles—W = 45 + 5 deg, −0 deg; X = 118 ± 5 deg; Y = (see Table); Z = 35 + 5 deg, −0 deg.

Socket Depth, T—Maximum socket depth, T, should not exceed three fourths of minimum head height, H.

Socket End Chamfer, V—Socket end of screw shall be flat and chamfered. The flat shall be normal to the axis of the screw and the chamfer, V, shall be at an angle of 35 + 5 deg, −0 deg with the surface of the flat. The chamfer shall extend to the bottom of the thread, and the edge between flat and chamfer shall be slightly rounded.

Length, L—The length of the screw shall be measured overall on a line parallel to the axis. The difference between consecutive lengths shall be as follows:

1. for screw lengths 1/4 to 5/8 in., difference = 1/16 in.
2. for screw lengths 5/8 to 1 in., difference = 1/8 in.
3. for screw lengths 1 to 4 in., difference = 1/4 in.
4. for screw lengths 4 to 6 in., difference = 1/2 in.

Length Tolerance—Allowable tolerance on length, L, shall be 3% on lengths 2 in. and under with a minimum of 0.020 in., one half to be applied plus and one half minus; on lengths over 2 in. to 6 in. plus or minus 1/32 in.; on lengths over 6 in. plus or minus 1/16 in.

Screw Threads shall conform to the American Standard Screw Threads, ASA B1.1.

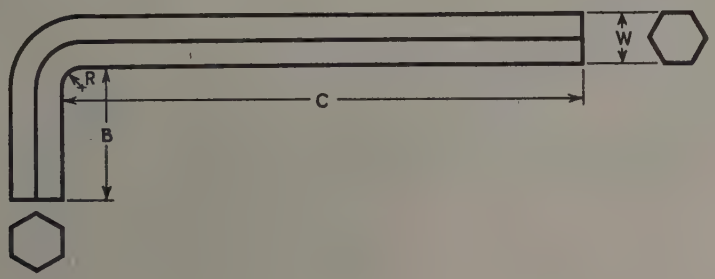


TABLE 4—*Dimensions of Keys for Hexagon Socket-Head Capscrews and Setscrews*[a]

D		W		B		C				R
Screw size		Hexagon width across flats		Length short arm		Length long arm				Radius of bend
						Short series		Long series		
Cap	Set	Max	Min	Max	Min	Max	Min	Max	Min	
2	5	1/16	0.0615	21/32	15/32	1 27/32	1 21/32	—	—	1/16
2	6	1/16	0.0615	21/32	15/32	1 27/32	1 21/32	—	—	1/16
3, 4	8	5/64	0.0771	45/64	33/64	1 31/32	1 25/32	—	—	5/64
5, 6	10	3/32	0.0927	3/4	9/16	2 3/32	1 29/32	—	—	3/32
5, 6	12	3/32	0.0927	3/4	9/16	2 3/32	1 29/32	—	—	3/32
8	1/4	1/8	0.1235	27/32	21/32	2 11/32	2 5/32	3 27/32	3 21/32	1/8
10, 12	5/16	5/32	0.1547	15/16	3/4	2 19/32	2 13/32	4 7/32	4 1/32	5/32
1/4	3/8	3/16	0.1860	1 1/32	27/32	2 27/32	2 21/32	4 19/32	4 13/32	3/16
5/16	7/16	7/32	0.2172	1 1/8	15/16	3 3/32	2 29/32	4 31/32	4 25/32	7/32
—	1/2	1/4	0.2485	1 7/32	1 1/32	3 11/32	3 5/32	5 11/32	5 5/32	1/4
—	9/16	1/4	0.2485	1 7/32	1 1/32	3 11/32	3 5/32	5 11/32	5 5/32	1/4
3/8, 7/16	5/8	5/16	0.3110	1 11/32	15/32	3 27/32	3 21/32	6 3/32	5 29/32	5/16
1/2, 9/16	3/4	3/8	0.3735	1 15/32	1 9/32	4 11/32	4 5/32	6 27/32	6 21/32	3/8
5/8	7/8	1/2	0.4985	1 23/32	1 17/32	5 11/32	5 5/32	8 11/32	8 5/32	1/2
—	1	9/16	0.5600	1 27/32	1 21/32	5 27/32	5 21/32	9 3/32	8 29/32	9/16
3/4, 7/8	1 1/8	9/16	0.5600	1 27/32	1 21/32	5 27/32	5 21/32	9 3/32	8 29/32	9/16
1	1 1/4, 1 3/8	5/8	0.6225	1 31/32	1 25/32	6 11/32	6 5/32	9 27/32	9 21/32	5/8
1 1/8, 1 1/4, 1 3/8	1 1/2	3/4	0.7475	2 7/32	2 1/32	7 11/32	7 5/32	11 11/32	11 5/32	3/4
—	1 3/4	1	0.9975	2 23/32	2 17/32	9 11/32	9 5/32	14 11/32	14 5/32	1
1 1/2	2	1	0.9975	2 23/32	2 17/32	9 11/32	9 5/32	14 11/32	14 5/32	1

[a] All dimensions are in inches.

Round Unslotted-Head Bolts

SAE Standard

Report of Screw Threads Division approved February 1929 and last revised January 1942. This SAE Standard conforms with American Standard for Round Unslotted-Head Bolts, Carriage, Step , and Machine Bolts, ASA B18.5—1939.

[This SAE Standard is sponsored by ASME and SAE under ASA procedure. It is primarily for use in the motor-vehicle and agricultural-implement industries but is recommended for other constructions where these types of bolts are used.]

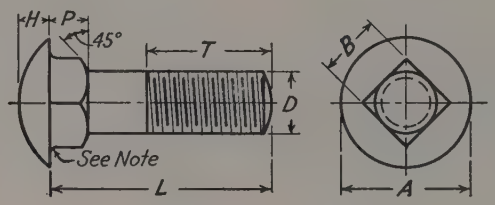


TABLE 1—*Square-Neck Carriage Bolt*[a]

NOMINAL BOLT DIAMETER, *D*	DIAMETER OF HEAD, *A*		HEIGHT OF HEAD, *H*		DEPTH OF SQUARE, *P*			WIDTH OF SQUARE, *B*	
	Min	Max	Min	Max	For bolt lengths	Min	Max	Min	Max
No. 10	(7/16) 0.438	0.469	(3/32) 0.094	0.114	1 1/8 and shorter 1 1/4 and longer	0.094 0.188	0.125 0.219	0.185	0.199
1/4	(9/16) 0.563	0.594	(1/8) 0.125	0.145	1 1/4 and shorter 1 3/8 and longer	0.125 0.219	0.156 0.250	0.245	0.260
5/16	(11/16) 0.688	0.719	(5/32) 0.156	0.176	1 1/4 and shorter 1 3/8 and longer	0.156 0.250	0.187 0.281	0.307	0.324
3/8	(13/16) 0.813	0.844	(3/16) 0.188	0.208	1 1/2 and shorter 1 5/8 and longer	0.188 0.281	0.219 0.312	0.368	0.388
7/16	(15/16) 0.938	0.969	(7/32) 0.219	0.239	1 1/2 and shorter 1 5/8 and longer	0.219 0.313	0.250 0.344	0.431	0.452
1/2	(1 1/16) 1.063	1.094	(1/4) 0.250	0.270	1 7/8 and shorter 2 and longer	0.250 0.344	0.281 0.375	0.492	0.515
9/16	(1 3/16) 1.188	1.219	(9/32) 0.281	0.312	1 7/8 and shorter 2 and longer	0.281 0.375	0.312 0.406	0.554	0.579
5/8	(1 5/16) 1.313	1.344	(5/16) 0.313	0.344	1 7/8 and shorter 2 and longer	0.313 0.406	0.344 0.437	0.616	0.642
3/4	(1 9/16) 1.563	1.594	(3/8) 0.375	0.406	1 7/8 and shorter 2 and longer	0.375 0.469	0.406 0.500	0.741	0.768
7/8	(1 13/16) 1.813	1.844	(7/16) 0.438	0.469	1 7/8 and shorter 2 and longer	0.438 0.531	0.469 0.562	0.865	0.895
1	(2 1/16) 2.063	2.094	(1/2) 0.500	0.531	1 7/8 and shorter 2 and longer	0.500 0.594	0.531 0.625	0.990	1.022

[a] All dimensions are in inches.
Maximum radius of fillet under head of bolt for sizes No. 10 (0.1900) to 1/2 in. inclusive, shall be 1/32 in.; and for sizes 9/16 to 1 in. inclusive, shall be 1/16 in.
Length of bolt, *L*, is measured from under the head to the end of the bolt.
The screw threads of these bolts shall conform to the coarse-thread series of the American Standard Screw Threads, ASA B1.1—1935.
These bolts may be supplied with either rolled or cut threads. Rolled-thread bolts are not pointed.
For thread length, *T*, see Appendix.

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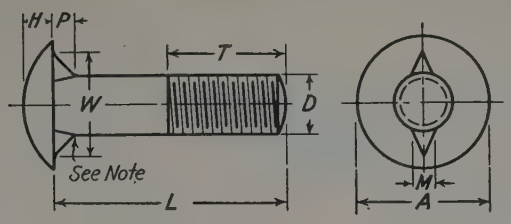

TABLE 2—*Fin-Neck Carriage Bolt*[a]

NOMINAL BOLT DIAMETER, *D*	DIAMETER OF HEAD, *A*		HEIGHT OF HEAD, *H*		DEPTH OF FINS, *P*		DISTANCE ACROSS FINS, *W*		THICKNESS OF FINS, *M*	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
No. 10	(15/32) 0.469	0.489	(5/64) 0.078	0.098	(5/64) 0.078	0.088	(3/8) 0.375	0.395	(5/64) 0.078	0.098
1/4	(19/32) 0.594	0.614	(7/64) 0.109	0.129	(3/32) 0.094	0.104	(7/16) 0.438	0.458	(3/32) 0.094	0.114
5/16	(23/32) 0.719	0.739	(9/64) 0.141	0.161	(1/8) 0.125	0.135	(17/32) 0.531	0.551	(1/8) 0.125	0.145
3/8	(27/32) 0.844	0.864	(11/64) 0.172	0.192	(9/64) 0.141	0.151	(5/8) 0.625	0.645	(9/64) 0.141	0.161
7/16	(31/32) 0.969	0.989	(13/64) 0.203	0.223	(11/64) 0.172	0.182	(23/32) 0.719	0.739	(11/64) 0.172	0.192
1/2	(1 3/32) 1.094	1.114	(15/64) 0.234	0.254	(3/16) 0.188	0.198	(13/16) 0.813	0.833	(3/16) 0.188	0.208

[a] All dimensions are in inches.
Maximum radius of fillet under head of bolt for sizes No. 10 (0.1900) to 1/2 in. inclusive, shall be 1/32 in.
Length of bolt, *L*, is measured from under the head to the end of the bolt.
The screw threads of these bolts shall conform to the coarse-thread series of the American Standard Screw Threads, ASA B1.1—1935.
These bolts may be supplied with either rolled or cut threads. Rolled-thread bolts are not pointed.
For thread length, *T*, see Appendix.

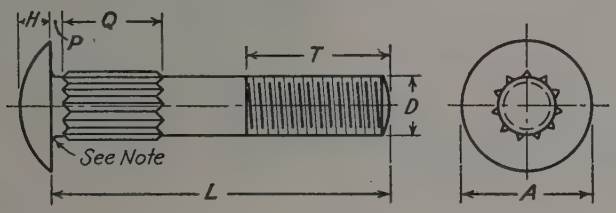

TABLE 3—*Ribbed-Neck Carriage Bolt*[a]

NOMINAL BOLT DIAMETER, *D*	DIAMETER OF HEAD, *A*		HEIGHT OF HEAD, *H*		DISTANCE OF RIBS BELOW HEAD, *P*			LENGTH OF RIBS, *Q*			NUMBER OF RIBS
	Min	Max	Min	Max	For *L*, 7/8 or less	For *L*, 1 or more	Tolerance ±	For *L*, 7/8 or less	For *L*, 1 and 1 1/8	For *L*, 1 1/4 or more	
No. 10	(7/16) 0.438	0.469	(3/32) 0.094	0.114	0.031	0.063	0.031	0.188	0.313	0.500	9
1/4	(9/16) 0.563	0.594	(1/8) 0.125	0.145	0.031	0.063	0.031	0.188	0.313	0.500	10
5/16	(11/16) 0.688	0.719	(5/32) 0.156	0.176	0.031	0.063	0.031	0.188	0.313	0.500	12
3/8	(13/16) 0.813	0.844	(3/16) 0.188	0.208	0.031	0.063	0.031	0.188	0.313	0.500	12
7/16	(15/16) 0.938	0.969	(7/32) 0.219	0.239	0.031	0.063	0.031	0.188	0.313	0.500	14
1/2	(1 1/16) 1.063	1.094	(1/4) 0.250	0.270	0.031	0.063	0.031	0.188	0.313	0.500	16
9/16	(1 3/16) 1.188	1.219	(9/32) 0.281	0.312	0.094	0.094	0.031	0.188	0.313	0.500	18
5/8	(1 5/16) 1.313	1.344	(5/16) 0.313	0.344	0.094	0.094	0.031	0.188	0.313	0.500	19
3/4	(1 9/16) 1.563	1.594	(3/8) 0.375	0.406	0.094	0.094	0.031	0.188	0.313	0.500	22

[a] All dimensions are in inches.
Maximum radius of fillet under head of bolt for sizes No. 10 (0.1900) to 1/2 in. inclusive, shall be 1/32 in.; and for sizes 9/16 to 3/4 in. inclusive, shall be 1/16 in.
Included angle of ribs shall be approximately 90 deg.
Length of bolt, *L*, is measured from under the head to the end of the bolt.
The screw threads of these bolts shall conform to the coarse-thread series of the American Standard Screw Threads, ASA B1.1—1935.
These bolts may be supplied with either rolled or cut threads. Rolled-thread bolts are not pointed.
For thread length, *T*, see Appendix.

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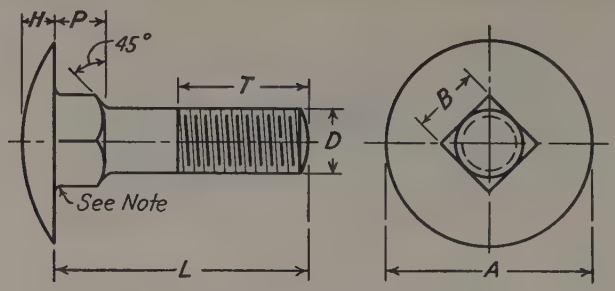


TABLE 4—*Step Bolt or Oval-Head Elevator Bolt* [a]

NOMINAL BOLT DIAMETER, *D*	HEAD DIAMETER, *A*		HEAD HEIGHT, *H*		DEPTH OF SQUARE, *P*			WIDTH OF SQUARE, *B*	
	Min	Max	Min	Max	For bolt lengths	Min	Max	Min	Max
No. 10	0.625	0.656	0.094	0.114	1⅛ and shorter	0.094	0.125	0.185	0.199
					1¼ and longer	0.188	0.219		
¼	0.813	0.844	0.125	0.145	1¼ and shorter	0.125	0.156	0.245	0.260
					1⅜ and longer	0.219	0.250		
5/16	1.000	1.031	0.156	0.176	1¼ and shorter	0.156	0.187	0.307	0.324
					1⅜ and longer	0.250	0.281		
⅜	1.188	1.219	0.188	0.208	1½ and shorter	0.188	0.219	0.368	0.388
					1⅝ and longer	0.281	0.312		
7/16	1.375	1.406	0.219	0.239	1½ and shorter	0.219	0.250	0.431	0.452
					1⅝ and longer	0.313	0.344		
½	1.563	1.594	0.250	0.270	1⅞ and shorter	0.250	0.281	0.492	0.515
					2 and longer	0.344	0.375		

[a] All dimensions are in inches.
Maximum radius of fillet under head of bolt for sizes No. 10 (0.1900) to ½ in. inclusive, shall be 1/32 in.
Length of bolt, *L*, is measured from under the head to the end of the bolt.
The screw threads of these bolts shall conform to the coarse-thread series of the American Standard Screw Thread, ASA B1.1—1935.
These bolts may be supplied with either rolled or cut threads. Rolled-thread bolts are not pointed.
For thread length, *T*, see Appendix.

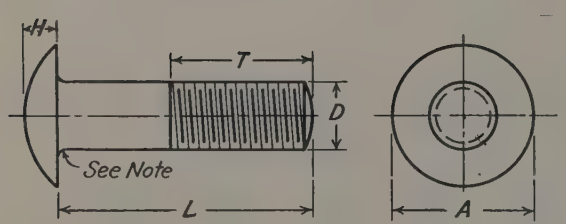


TABLE 5—*Button-Head Bolt* [a]

NOMINAL BOLT DIAMETER, *D*	HEAD DIAMETER, *A*		HEAD HEIGHT, *H*	
	Min	Max	Min	Max
No. 10	(7/16) 0.438	0.469	(3/32) 0.094	0.114
¼	(9/16) 0.563	0.594	(⅛) 0.125	0.145
5/16	(11/16) 0.688	0.719	(5/32) 0.156	0.176
⅜	(13/16) 0.813	0.844	(3/16) 0.188	0.208
7/16	(15/16) 0.938	0.969	(7/32) 0.219	0.239
½	(1 1/16) 1.063	1.094	(¼) 0.250	0.270
9/16	(1 3/16) 1.188	1.219	(9/32) 0.281	0.312
⅝	(1 5/16) 1.313	1.344	(5/16) 0.313	0.344
¾	(1 9/16) 1.563	1.594	(⅜) 0.375	0.406
⅞	(1 13/16) 1.813	1.844	(7/16) 0.438	0.469
1	(2 1/16) 2.063	2.094	(½) 0.500	0.531

[a] All dimensions are in inches.
Maximum radius of fillet under head of bolt for sizes No. 10 (0.1900) to ½ in. inclusive, shall be 1/32 in.; and for sizes 9/16 to 1 in. inclusive, shall be 1/16 in.
Length of bolt, *L*, is measured from under the head to the end of the bolt.
The screw threads of these bolts shall conform to the coarse-thread series of the American Standard Screw Threads, ASA B1.1—1935.
These bolts may be supplied with either rolled or cut threads. Rolled-thread bolts are not pointed.
For thread length, *T*, see Appendix.

(*Continued on next page.*)

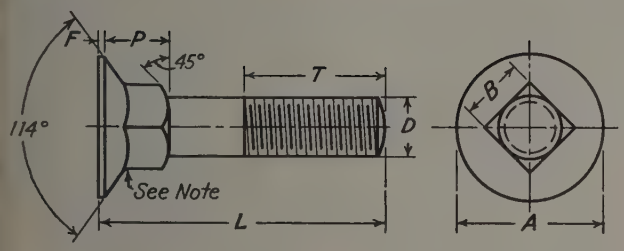


TABLE 6—*Countersunk Carriage Bolt*[a]

NOMINAL BOLT DIAMETER, *D*	HEAD DIAMETER, *A*		FEED THICKNESS, *F*	DEPTH OF SQUARE AND COUNTERSINK, *P*		WIDTH OF SQUARE, *B*	
	Min	Max		Min	Max	Min	Max
No. 10	(1/2) 0.500	0.520	0.016	(7/32) 0.219	0.250	0.185	0.199
1/4	(5/8) 0.625	0.645	0.016	(9/32) 0.281	0.312	0.245	0.260
5/16	(3/4) 0.750	0.770	0.031	(11/32) 0.344	0.375	0.307	0.324
3/8	(7/8) 0.875	0.895	0.031	(13/32) 0.406	0.437	0.368	0.388
7/16	(1) 1.000	1.020	0.031	(15/32) 0.469	0.500	0.431	0.452
1/2	(1 1/8) 1.125	1.145	0.031	(17/32) 0.531	0.562	0.492	0.515
9/16	(1 1/4) 1.250	1.275	0.031	(19/32) 0.594	0.625	0.554	0.579
5/8	(1 3/8) 1.375	1.400	0.031	(21/32) 0.656	0.687	0.616	0.642
3/4	(1 5/8) 1.625	1.650	0.047	(25/32) 0.781	0.812	0.741	0.768

[a] All dimensions are in inches.
Maximum radius of fillet under head of bolt for sizes No. 10 (0.1900) to ½ in. inclusive, shall be 1/32 in.; and for sizes 9/16 to ¾ in inclusive, shall be 1/16 in.
Tolerance for included angle of head is plus 2 deg.
Length of bolt, *L*, is the overall length.
The screw threads of these bolts shall conform to the coarse-thread series of the American Standard Screw Threads, ASA B1.1—1935.
These bolts may be supplied with either rolled or cut threads. Rolled-thread bolts are not pointed.
For thread length, *T*, see Appendix.

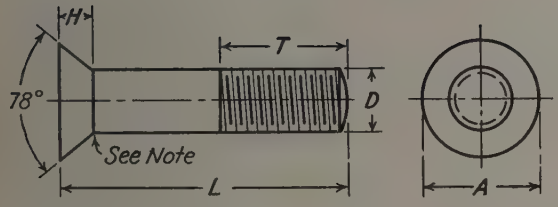


TABLE 7—*Countersunk Bolt*[a]

NOMINAL BOLT DIAMETER, *D*	DIAMETER OF HEAD, *A*			DEPTH OF HEAD, *H*
	Basic	Max	Min	
1/2	0.905	0.936	0.874	0.250
9/16	1.018	1.049	0.987	0.281
5/8	1.131	1.194	1.068	0.313
3/4	1.358	1.421	1.295	0.375
7/8	1.584	1.647	1.521	0.438
1	1.810	1.873	1.747	0.500
1 1/8	2.036	2.114	1.973	0.563
1 1/4	2.263	2.341	2.200	0.625
1 3/8	2.489	2.567	2.426	0.688
1 1/2	2.715	2.793	2.652	0.750
1 5/8	2.941	3.019	2.878	0.813
1 3/4	3.168	3.262	3.105	0.875
1 7/8	3.394	3.488	3.331	0.938
2	3.620	3.714	3.557	1.000

[a] All dimensions are in inches.
Maximum radius of fillet under head of bolt for sizes ½ in. to 2 in. inclusive, shall be 1/16 in.
The depth of head, *H*, is given for construction purposes only. Variations in this dimension are controlled by the diameters, *A* and *D*, and the included angle of the head
Tolerance for included angle of head is plus 2 deg.
Length of bolt, *L*, is the overall length.
The screw threads of these bolts shall conform to the coarse-thread series of the American Standard Screw Threads, ASA B1.1—1935.
These bolts may be supplied with either rolled or cut threads. Rolled-thread bolts are not pointed.
For thread length, *T*, see Appendix.
For sizes smaller than ½ in., see American Standard for Slotted-Head Proportions, B18c—1930 (Flat-Head Capscrews)

(*Continued on next page.*)

Appendix

TABLE 8—*Minimum Usable Thread Lengths of Round Unslotted-Head Bolts* [a]

BOLT LENGTH,[b] L	NOMINAL BOLT DIAMETER, D										
	No. 10, ¼	5/16, 3/8	7/16, ½	9/16, 5/8	¾	⅞	1	1⅛, 1¼	1⅜, 1½	1⅝, 1¾	1⅞, 2
	Minimum usable thread length,[c] T										
¾	½	½	—	—	—	—	—	—	—	—	—
1	¾	¾	¾	¾	—	—	—	—	—	—	—
1¼	¾	¾	1	1	1	—	—	—	—	—	—
1½	¾	⅞	1	1⅛	1⅛	1⅛	—	—	—	—	—
1¾	¾	⅞	1	1 3/16	1⅜	1⅜	1⅜	—	—	—	—
2	¾	1	1¼	1¼	1⅜	1 9/16	1⅝	1⅝	—	—	—
2½	¾	1	1¼	1½	1½	1 9/16	1¾	2	2	—	—
3	⅞	1	1¼	1½	1¾	1¾	1¾	2⅛	2½	2½	—
4	⅞	1	1¼	1½	1¾	2	2¼	2¼	2½	2⅞	3¼
5	⅞	1 3/16	1¼	1½	1¾	2	2¼	2¾	2¾	2⅞	3¼
6	⅞	1 3/16	1½	1½	1¾	2	2¼	2¾	3¼	3¼	3¼
8	⅞	1 3/16	1½	1 3/16	2	2	2¼	2¾	3¼	3¾	4
10	⅞	1 3/16	1½	1 3/16	2⅛	2 7/16	2½	2¾	3¼	3¾	4¼
12	⅞	1 3/16	1½	1 3/16	2⅛	2 7/16	2¾	2¾	3¼	3¾	4¼
16	1	1 3/16	1½	1 3/16	2⅛	2 7/16	2¾	3¼	3¼	3¾	4¼
20	1	1⅜	1½	1 3/16	2⅛	2 7/16	2¾	3⅜	4	4⅝	4¾
30	—	—	1¾	1 3/16	2⅛	2 7/16	2¾	3⅜	4	4⅝	5¼

[a] All dimensions are in inches.
[b] Bolt length, L, is measured from the greatest diameter of the bearing surface of (or, under) the head to the end of the bolt, in a line parallel to the axis of the bolt.
[c] Minimum thread length, T, is measured from the extreme end of the bolt to the last complete thread.
Length of incomplete thread shall not exceed 2½ threads.
Tolerances for bolt lengths 6 in. and under are ±1/32 in. for diameters ¼ to 3/8 in. inclusive; ±1/16 in. for diameters 7/16 and ½ in.; ± 1/8 in. for diameters 5/8 to 1¼ in. inclusive; ±¼ in. for diameters 1⅜ to 2 in. inclusive.
Tolerances for bolt lengths over 6 in. are ±1/16 in. for diameters ¼ to 3/8 in. inclusive; ±3/32 in. for diameters 7/16 and ½ in.; ±3/16 in. for diameters 5/8 to 1¼ in. inclusive; and ±¼ in. for diameters 1⅜ to 2 in. inclusive.
For intermediate bolt lengths, the minimum thread length shall be the same as that specified in the table for the next shorter bolt of the same diameter.
Bolts too short for the specified minimum thread length shall be threaded to within ¼ in. of the head or neck on sizes No. 10 to ½ in. inclusive; 3/8 in. on sizes 9/16 to 1 in. inclusive; and ½ in. on sizes 1⅛ to 2 in. inclusive.

Connecting-Rod Bolts

SAE Standard

Report of Engine Division approved August 1920 and last revised by Gasoline Engine Division January 1941.

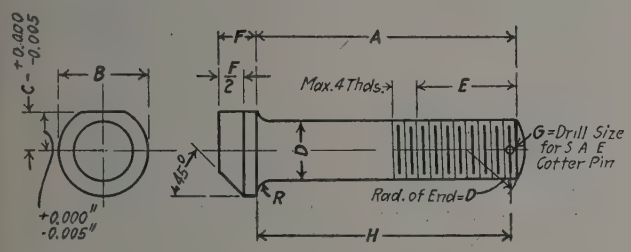


FIG. 1—CONNECTING-ROD BOLT

TABLE 1—*Dimensions for Connecting-Rod Bolts*[a]

BOLT SIZE,[b] TPI	A	B	C	D	E[c]	F	G, NO.	H, LENGTH, MINUS	R
5/16–24	Lengths vary by even 1/8 in., preferably by 1/4 in.	9/16	3/16	0.3125 0.3105	1/2	3/16	48	3/32	0.01 to 1/32
3/8 –24		5/8	7/32	0.3750 0.3730	5/8	7/32	36	9/64	
7/16–20		11/16	1/4	0.4375 0.4355	11/16	1/4	36	9/64	
1/2 –20		3/4	9/32	0.5000 0.4975	3/4	9/32	36	9/64	1/64 to 3/64
9/16–18		7/8	5/16	0.5625 0.5600	7/8	5/16	28	3/16	
5/8 –18		1	3/8	0.6250 0.6220	1	3/8	28	3/16	
3/4 –16		1 1/8	7/16	0.7500 0.7470	1 1/8	7/16	28	3/16	1/32 to 1/16
7/8 –14		1 3/8	1/2	0.8750 0.8715	1 1/4	1/2	28	3/16	
1 –14		1 1/2	9/16	1.0000 0.9965	1 1/2	5/8	28	3/16	

[a] Recommended practice for material is high-strength steel, heat-treated.
[b] Threads are NF—3.
[c] Minimum length of usable threads.

High Nuts

SAE Standard

Report of Screw Threads Division approved July 1924 and last revised January 1942.

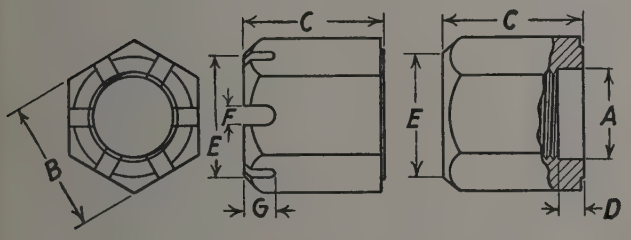


FIG. 1—DIMENSIONS OF HIGH NUTS

Note—The angle of chamfer shall not exceed 40 deg with top face of nut

TABLE 1—*Dimensions of High Nuts*[a]

SIZE, A	B	C	D[b]	E	F	G
1/4	7/16	3/8	1/16	25/64	5/64	3/32
5/16	1/2	29/64	5/64	29/64	3/32	3/32
3/8	9/16	17/32	3/32	33/64	1/8	1/8
7/16	5/8	39/64	7/64	37/64	1/8	5/32
1/2	3/4	11/16	1/8	11/16	5/32	5/32
9/16	7/8	49/64	9/64	51/64	5/32	3/16
5/8	1	27/32	5/32	55/64	3/16	7/32
3/4	1 1/8	1	3/16	63/64	3/16	1/4
7/8	1 5/16	1 5/32	7/32	1 5/32	3/16	1/4
1	1 1/2	1 5/16	1/4	1 21/64	1/4	9/32

[a] All screw threads shall be Class 2 fit as given in the SAE Standard for Screw Threads.
[b] The counterbore indicated is optional.

Cap (or Acorn) Nuts

SAE Recommended Practice

Report of Screw Threads Division approved January 1933 and last revised January 1942.

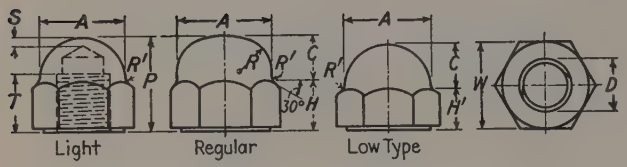


FIG. 1—DIMENSIONS OF CAP NUTS

Cap-nut construction may be either solid or two-piece construction.

A, for sizes No. 6 to 7/16 in., inclusive, equals hexagon size — 1/32 in.; and for sizes 1/2 to 1 1/4 in., inclusive, equals hexagon size — 1/16 in.

H, for No. 6 to No. 10, inclusive, equals *D*; for No. 12 to 1 1/4 in., inclusive, equals 7/8 *D*.

H', for low nuts, light series only, equals 3/4 *D*.

R', radius for sizes No. 6 to 7/16 in., inclusive, equals 1/64 in.; for sizes 1/2 to 1 1/4 in., inclusive, equals 1/32 in.

The thread in the hole is to be countersunk 35 deg with the face of the nut and to the diameter of the tap.

T, depth of usable thread for the low-type nuts, must be reduced by the amount $H - H'$.

TABLE 1—*Dimensions of Cap Nuts*

NUT SIZE, *D*	*C*	WIDTH OF FLATS, *W*[a]		RADIUS, *R*	*S*, MIN	*T*	*P*
		Light	Regular				
No. 6	3/16	5/16	—	9/64	1/32	9/64	19/64
No. 8	3/16	5/16	—	9/64	1/32	5/32	5/16
No. 10	15/64	3/8	—	11/64	1/32	3/16	25/64
No. 12	15/64	3/8	—	11/64	1/32	7/32	27/64
1/4	1/4	7/16	7/16	3/16	3/64	1/4	15/32
5/16	17/64	1/2	9/16	13/64	3/64	5/16	17/32
3/8	19/64	9/16	5/8	15/64	3/64	3/8	5/8
7/16	11/32	5/8	3/4	9/32	3/64	7/16	23/32
1/2	3/8	3/4	13/16	5/16	3/64	1/2	13/16
9/16	7/16	7/8	7/8	3/8	1/16	9/16	15/16
5/8	7/16	15/16	1	3/8	1/16	5/8	63/64
3/4	17/32	1 1/16	1 1/8	7/16	1/16	3/4	1 3/16
7/8	39/64	1 1/4	1 5/16	33/64	3/32	7/8	1 3/8
1	11/16	1 7/16	1 1/2	19/32	3/32	1	1 9/16
1 1/8	25/32	1 5/8	1 11/16	43/64	3/32	1 1/8	1 25/32
1 1/4	27/32	1 13/16	1 7/8	47/64	3/32	1 1/4	1 15/16

[a] The width across flats of these nuts conforms to the American Standard as revised in 1933, except Nos. 8 and 12 in the light series, as shown.

Slots in Plain Nuts

SAE Recommended Practice

Report of Screw Threads Division approved June 1931 and last revised January 1942.

TABLE 1—*Dimensions of Slots in Plain Nuts*

NOMINAL NUT SIZE, IN.	NUT THICKNESS	SLOT DIMENSIONS, IN.		NOMINAL NUT SIZE, IN.	NUT THICKNESS	SLOT DIMENSIONS, IN.	
		Width	Depth			Width	Depth
1/4	7/32	5/64	3/32	3/4	21/32	3/16	1/4
5/16	17/64	3/32	3/32	7/8	49/64	3/16	1/4
3/8	21/64	1/8	1/8	1	7/8	1/4	9/32
7/16	3/8	1/8	5/32	1 1/8	63/64	1/4	11/32
1/2	7/16	5/32	5/32	1 1/4	1 3/32	5/16	3/8
9/16	31/64	5/32	3/16	1 3/8	1 13/64	5/16	3/8
5/8	35/64	3/16	7/32	1 1/2	1 5/16	3/8	7/16

Alignment of Nut Slots

SAE General Information

Report of Screw Threads Division approved February 1925 and last revised January 1942.

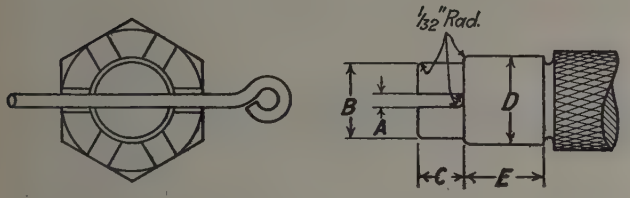


FIG. 1—GAGE DIMENSIONS

This method of gaging castle-nut slots permits as much varia tion in the location of the cotter-pin hole in the screw as in the nut. Some approximations will have to be made in application of this method owing to differences of bore due to the drilling and to tapping the nut. Errors can be reduced by the nut manufacturer by making the diameter of the plug suitable for the minimum drilled hole and by the user by making the plug suitable for the minimum minor diameter of the threaded hole. The gaging-pin diameter is intended to be the mean of the slot width in the gage and the cotter-pin diameter, the drilled-rod size nearest this dimension, but larger, being used. The diameter of the slotted part of the gage plug is smaller to clear burrs resulting from blanking and slotting the nut. See Table 1.

TABLE 1—*Gage Dimensions for Alignment of Nut Slots*

NUT	SLOT WIDTH[a]	COTTER-PIN DIAM[b]	DRILL ROD[c]		*A*	*B*	*C*	*D*[a]	*E*
			No.	In.					
1/4	5/64	1/16	49	0.073	0.073	0.182	5/32	0.2113	1/4
5/16	3/32	1/16	45	0.082	0.082	15/64	5/32	0.2674	19/64
3/8	1/8	3/32	34	0.110	0.110	19/64	3/16	0.3299	11/32
7/16	1/8	3/32	34	0.110	0.110	11/32	3/16	0.3834	25/64
1/2	5/32	3/32	28	0.141[d]	0.141[d]	13/32	1/4	0.4459	7/16

[a] Minimum minor diameter for Class 2 nuts. If the nuts are not threaded in accordance with the SAE Standard for Screw Threads, the diameter shall be the same as the diameter of the Go-plug gage for the bore.
[b] SAE Standard Cotter-Pin dimensions.
[c] The drill rod should preferably be tempered and should fit in the slot of the gage without shake.
[d] This dimension or 9/64.

Slots and Cotter-Pin Holes, Capscrews and Bolts

SAE Recommended Practice

Report of Screw Threads Division approved July 1926 and last revised January 1942.

TABLE 1—*Dimensions for Slots and Cotter-Pin Holes*

NOMINAL CAP-SCREW AND BOLT DIAMETER	COTTER-PIN HOLE DIAMETER	HEAD SLOTS		CENTER OF COTTER-PIN HOLE TO EXTREME POINT OF SCREW,[a] IN.	NOMINAL CAP-SCREW AND BOLT DIAMETER	COTTER-PIN-HOLE DIAMETER	HEAD SLOTS		CENTER OF COTTER-PIN HOLE TO EXTREME POINT OF SCREW,[a] IN.
		Width	Depth, max				Width	Depth, max	
1/4	5/64	1/16	3/32	7/64	5/8	5/32	3/32	1/8	3/16
5/16	5/64	1/16	7/64	1/8	3/4	5/32	3/32	1/8	7/32
3/8	1/8	3/32	1/8	5/32	7/8	5/32	3/32	1/8	1/4
7/16	1/8	3/32	1/8	5/32	1	5/32	3/32	1/8	1/4
1/2	1/8	3/32	1/8	11/64	1 1/8	7/32	5/32	7/32	9/32
9/16	5/32	3/32	1/8	3/16	1 1/4	7/32	5/32	7/32	9/32
					1 1/2	1/4	3/16	1/4	5/16

[a] This dimension is suggested to determine the distance from the cotter-pin hole to the under face of the screw head or bolt.

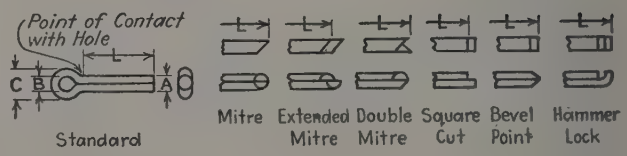
Cotter Pins

SAE Standard

Report of Miscellaneous Division approved August 1915 and last revised by Parts and Fittings Technical Committee January 1949.

TABLE 1—*Cotter-Pin Dimensions*

PIN DIAMETER, *A*			MINIMUM EYE DIAMETER		RECOMMENDED HOLE DIAMETER (DRILL SIZE)
Nominal	Max	Min	Inside, *B*	Outside, *C*	
1/32 (0.031)	0.032	0.028	1/32	1/16	3/64 (0.0469)
3/64 (0.047)	0.048	0.044	3/64	3/32	1/16 (0.0625)
1/16 (0.062)	0.060	0.056	1/16	1/8	5/64 (0.0781)
5/64 (0.078)	0.076	0.072	5/64	5/32	3/32 (0.0937)
3/32 (0.094)	0.090	0.086	3/32	3/16	7/64 (0.1094)
1/8 (0.125)	0.120	0.116	1/8	1/4	9/64 (0.1406)
5/32 (0.156)	0.150	0.146	5/32	5/16	11/64 (0.1719)
3/16 (0.188)	0.176	0.172	3/16	3/8	13/64 (0.2031)
7/32 (0.219)	0.207	0.202	7/32	7/16	15/64 (0.2344)
1/4 (0.250)	0.225	0.220	1/4	1/2	17/64 (0.2656)
5/16 (0.312)	0.280	0.275	5/16	5/8	5/16 (0.3125)
3/8 (0.375)	0.335	0.329	3/8	3/4	3/8 (0.3750)
1/2 (0.500)	0.473	0.467	1/2	1	1/2 (0.5000)



Some leeway is permissible in the design of the head, but the inside and outside diameters given should be adhered to.

Prongs are to be parallel; ends shall not be open.

Lengths, *L*, shall be measured as shown on the illustrations.

Cotter pins shall be free from burrs or any defects that will affect their serviceability.

Plain Washers

SAE Standard

Report of Parts and Fittings Division approved August 1922 and last revised by Parts and Fittings Technical Committee January 1949. This SAE Standard conforms to American Standard Plain Washers, ASA B27.2-1949, except for the manner of expressing thicknesses.

TABLE 1—*Dimensions of Plain Washers*

INSIDE DIAMETER,[a] IN.	OUTSIDE DIAMETER,[b] IN.	THICKNESS[c]		INSIDE DIAMETER,[a] IN.	OUTSIDE DIAMETER,[b] IN.	THICKNESS[c]		INSIDE DIAMETER,[a] IN.	OUTSIDE DIAMETER,[b] IN.	THICKNESS[c]	
		Max	Min			Max	Min			Max	Min
5/64	3/16	0.025	0.016	13/32	13/16	0.080	0.051	15/16	2	0.192	0.136
3/32	7/32	0.025	0.016	7/16	7/8	0.104	0.064	15/16	2 1/4	0.192	0.136
3/32	1/4	0.025	0.016	7/16	1	0.104	0.064	15/16	3 3/8	0.213	0.153
1/8	1/4	0.028	0.017	7/16	1 3/8	0.104	0.064	1 1/16	2	0.160	0.108
1/8	5/16	0.040	0.025	15/32	59/64	0.080	0.051	1 1/16	2 1/4	0.192	0.136
5/32	5/16	0.048	0.027	1/2	1 1/8	0.104	0.064	1 1/16	2 1/2	0.192	0.136
5/32	3/8	0.065	0.036	1/2	1 1/4	0.104	0.064	1 1/16	3 7/8	0.280	0.210
11/64	13/32	0.065	0.036	1/2	1 5/8	0.104	0.064	1 3/16	2 1/2	0.192	0.136
3/16	3/8	0.065	0.036	17/32	1 1/16	0.121	0.074	1 1/4	2 3/4	0.192	0.136
3/16	7/16	0.065	0.036	9/16	1 1/4	0.132	0.086	1 5/16	2 3/4	0.192	0.136
13/64	15/32	0.065	0.036	9/16	1 3/8	0.132	0.086	1 3/8	3	0.192	0.136
7/32	7/16	0.065	0.036	9/16	1 7/8	0.132	0.086	1 7/16	3	0.213	0.153
7/32	1/2	0.065	0.036	19/32	1 3/16	0.121	0.074	1 1/2	3 1/4	0.213	0.153
15/64	17/32	0.065	0.036	5/8	1 3/8	0.132	0.086	1 9/16	3 1/4	0.213	0.153
1/4	1/2	0.065	0.036	5/8	1 1/2	0.132	0.086	1 5/8	3 1/2	0.213	0.153
1/4	9/16	0.065	0.036	5/8	2 1/8	0.160	0.108	1 11/16	3 1/2	0.213	0.153
1/4	9/16	0.080	0.051	21/32	1 5/16	0.121	0.074	1 3/4	3 3/4	0.213	0.153
17/64	5/8	0.065	0.036	11/16	1 1/2	0.160	0.108	1 13/16	3 3/4	0.213	0.153
9/32	5/8	0.080	0.051	11/16	1 3/4	0.160	0.108	1 7/8	4	0.213	0.153
5/16	3/4	0.080	0.051	11/16	2 3/8	0.192	0.136	1 15/16	4	0.213	0.153
5/16	7/8	0.080	0.051	13/16	1 1/2	0.160	0.108	2	4 1/4	0.213	0.153
11/32	11/16	0.080	0.051	13/16	1 3/4	0.177	0.122	2 1/16	4 1/4	0.213	0.153
3/8	3/4	0.080	0.051	13/16	2	0.177	0.122	2 1/8	4 1/2	0.213	0.153
3/8	7/8	0.104	0.064	13/16	2 7/8	0.192	0.136	2 3/8	4 3/4	0.248	0.193
3/8	1 1/8	0.080	0.051	15/16	1 3/4	0.160	0.108	2 5/8	5	0.280	0.210
								2 7/8	5 1/4	0.310	0.228
								3 1/8	5 1/2	0.327	0.249

[a] Tolerance is ±0.005 on inside diameter to and including 7/32 inside diameter, and ±0.010 on inside diameter greater than 7/32.
[b] Tolerance is ±0.010 on outside diameter for all sizes.
[c] Thicknesses of washers are Birmingham gage. The limits given are a tolerance of plus or minus one gage, or the spread from the minimum of one gage minus to the maximum of one gage plus.

Lock Washers

SAE Standard

Report of Parts and Fittings Division approved August 1922 and last revised by Parts and Fittings Technical Committee January 1951. This SAE Standard conforms to American Standard Lock Washers, ASA B27.1-1950.

Introduction

Scope—This Standard gives the dimensions, physical properties, and methods of testing of spring lock washers in various materials; carbon-steel tooth lock washers; spring lock washers and machine-screw assemblies; and carbon-steel tooth lock washers and machine-screw assemblies.

Spring Lock Washers—The spring lock washers covered by this Standard are intended for automotive and general industrial application. They have the dual function of: (1) spring take-up devices to compensate for developed looseness and the loss of tension between component parts of an assembly and (2) hardened thrust bearings to facilitate assembly and disassembly of bolted fastenings by decreasing the frictional resistance between the bolted surface and the bearing face of the bolt head or nut.

The Standard covers lock washers of carbon steel, stainless

steel Type 302, stainless steel Type 420, aluminum-zinc alloy, phosphor bronze Grade A, silicon bronze Type B, and K-Monel.

Tooth Lock Washers—The tooth lock washers covered by this Standard are intended for automotive and general industrial application. They serve to lock fasteners, such as bolts and nuts, to the component parts of an assembly, or increase the friction between the fasteners and the assembly.

The Standard applies to tooth lock washers with internal teeth, tooth lock washers with external teeth, and tooth lock washers with both internal and external teeth.

Spring Lock Washers and Machine-Screw Assemblies—The spring lock washer and machine-screw assemblies covered by this Standard are general-purpose fasteners for mass production and other operations where speed and convenience are paramount factors.

Tooth Lock Washers and Machine-Screw Assemblies—The tooth lock washer and machine-screw assemblies covered by this Standard are general-purpose fasteners for mass production and other operations where speed and convenience are paramount factors.

Spring Lock Washers

General Specifications—These general specifications apply and are common to spring lock washers of the various materials covered by this Standard.

The additional requirements peculiar to washers of a specific material are covered in the detailed specifications which follow.

Use and Application—Use and application of spring lock washers are described in Introduction.

Washer Section—The section of finished washers shall be slightly trapezoidal in shape with thickness at the inner periphery greater than the thickness at the outer periphery by an amount varying from a minimum of 0.0005 in. to a maximum of 0.001 in. per 0.0156 (1/64) in. of section width. The minimum thickness specified in the table of dimensions represents the nominal mean thickness of the trapezoid. Reduced to formulas, the increase in thickness from the outer periphery to inner periphery is T minus t or 0.032 W (minimum) to 0.064 W (maximum).

Coiling—Washers shall be coiled so that free height is approximately twice the thickness of washer section. Gap and relationship of severed ends shall be such as to prevent washers tangling.

Quality of Finish—The flat faces of washers and the inner and outer peripheries shall be smooth and free from knurling, serrations, die marks, and deep scratches, although slight feed-roll marks are permissible.

Washers shall also be free from burrs, rust, pit marks, and loose scale with internal and external circumferential edges rounded sufficiently to avoid checks.

Designation—Washers shall be specified or designated by the nominal size and the series, that is, 1/4 in. light, 1/4 in. medium, 1/4 in. heavy, or 1/4 in. extra heavy.

Dimensions—The dimensions of spring lock washers are as specified in Tables 2 to 5. Washers in certain materials are not available in all of the four series covered by those tables. For the series in which washers are available see the detailed specifications which follow.

Temper Test—After compressing to flat and releasing, the free height of a washer shall be at least two thirds of the original free height.

Twist Test—A portion of washer shall be firmly gripped in vise jaws having sharp edges. The ends of the washer shall be free and an axis passing through the slot shall be parallel to the top of the vise. An equal portion of the washer shall be gripped in wrench jaws. Edges of the wrench jaws shall be sharp and in a plane parallel to the top of the vise. Between the grip of the vice and the wrench approximately 25% of the washer shall be exposed. For convenience and uniformity of test the distance between the vise and the wrench is specified in Table 1.

Movement of the wrench in a direction that increases the free height of the spring lock washer shall twist carbon-steel washers through an angle of 90 deg and stainless steel and nonferrous washers through an angle of 45 deg, without sign of fracture. When a washer fractures at a greater degree of twist, the structure at the point of fracture shall show a fine grain, and the washer up to the instant of fracture shall deliver a tough, springy reaction. (See Fig. 1.)

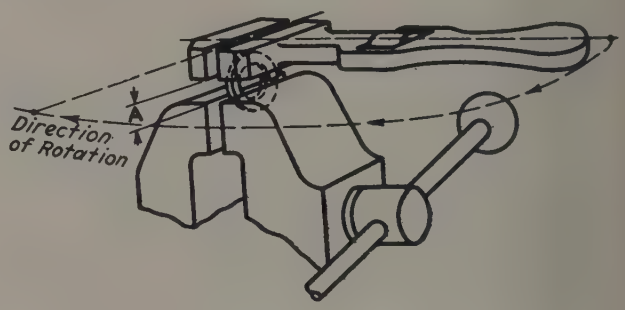


FIG. 1—CLEARANCE BETWEEN WRENCH AND VISE GRIP

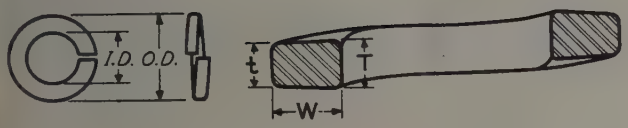
TABLE 1—*Clearance Between Wrench and Grip of Vise*[a]

NOMINAL WASHER SIZE	DIMENSION *A*
No. 2, 3, 4, 5, 6, 8	1/16
No. 10, 12	3/32
1/4, 5/16	1/8
3/8, 7/16	3/16
1/2, 9/16, 5/8	1/4
11/16, 3/4, 13/16	5/16
7/8, 15/16	3/8
1, 1 1/16	7/16
1 1/8, 1 3/16	15/32
1 1/4	1/2
1 5/16	17/32
1 3/8	9/16
1 7/16	19/32
1 1/2	5/8

[a] All dimensions are given in inches.

Referee Clamping Test—The clamping test consists of compressing 100 samples of each batch between hardened and ground steel plates. The washers are to be held compressed for 1 min and then inspected. If no washers are broken, they should again be clamped for 3 hr and reinspected and if no washers are broken, should be compressed a third time for 16 hr or longer.

(*Text continued after Table 5.*)



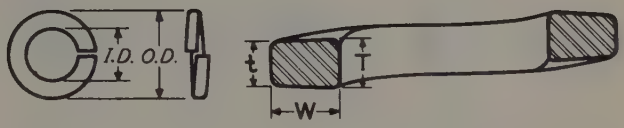


TABLE 2—*Dimensions of Light Spring Lock Washers*[a]

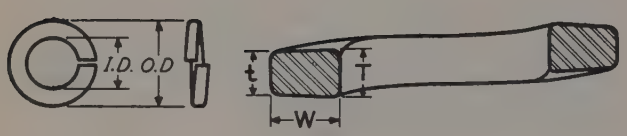
NOMINAL SIZE	INSIDE DIAMETER	CLEARANCE OF NOMINAL BOLT SIZE		WASHER SECTIONS, MIN		OUTSIDE DIAM
	Min	Min	Max	Width, w	Thickness, $\frac{T+t}{2}$	Max[b]
0.086 (No. 2)	0.088	0.002	0.011	0.030	0.015	0.165
0.099 (No. 3)	0.102	0.002	0.011	0.035	0.020	0.188
0.112 (No. 4)	0.115	0.003	0.012	0.035	0.020	0.202
0.125 (No. 5)	0.128	0.003	0.012	0.040	0.025	0.225
0.138 (No. 6)	0.141	0.003	0.013	0.040	0.025	0.239
0.164 (No. 8)	0.168	0.004	0.014	0.047	0.031	0.280
0.190 (No. 10)	0.194	0.004	0.015	0.055	0.040	0.323
0.216 (No. 12)	0.221	0.005	0.016	0.062	0.047	0.364
1/4	0.255	0.005	0.017	0.107	0.047	0.489
5/16	0.319	0.006	0.020	0.117	0.056	0.575
3/8	0.382	0.007	0.023	0.136	0.070	0.678
7/16	0.446	0.008	0.026	0.154	0.085	0.780
1/2	0.509	0.009	0.029	0.170	0.099	0.877
9/16	0.573	0.010	0.032	0.186	0.113	0.975
5/8	0.636	0.011	0.035	0.201	0.126	1.082
11/16	0.700	0.012	0.038	0.216	0.138	1.178
3/4	0.763	0.013	0.041	0.233	0.153	1.277
13/16	0.827	0.014	0.044	0.249	0.168	1.375
7/8	0.890	0.015	0.047	0.264	0.179	1.470
15/16	0.954	0.016	0.050	0.277	0.191	1.562
1	1.017	0.017	0.053	0.289	0.202	1.656
1 1/16	1.081	0.018	0.056	0.301	0.213	1.746
1 1/8	1.144	0.019	0.059	0.314	0.224	1.837
1 3/16	1.208	0.020	0.062	0.324	0.234	1.923
1 1/4	1.271	0.021	0.065	0.336	0.244	2.012
1 5/16	1.335	0.022	0.068	0.346	0.254	2.098
1 3/8	1.398	0.023	0.071	0.356	0.264	2.183
1 7/16	1.462	0.024	0.074	0.366	0.273	2.269
1 1/2	1.525	0.025	0.077	0.375	0.282	2.352

[a] All dimensions are given in inches.
For increased thickness due to taper, see paragraph covering washer section.
[b] The maximum outside diameters specified allow for the commercial tolerances on cold-drawn wire and hot-rolled rod.

TABLE 3—*Dimensions of Medium Spring Lock Washers*[a]

NOMINAL SIZE	INSIDE DIAMETER	CLEARANCE OF NOMINAL BOLT SIZE		WASHER SECTIONS, MIN		OUTSIDE DIAM
	Min	Min	Max	Width, w	Thickness, $\frac{T+t}{2}$	Max[b]
0.086 (No. 2)	0.088	0.002	0.011	0.035	0.020	0.175
0.099 (No. 3)	0.102	0.002	0.011	0.040	0.025	0.198
0.112 (No. 4)	0.115	0.003	0.012	0.040	0.025	0.212
0.125 (No. 5)	0.128	0.003	0.012	0.047	0.031	0.239
0.138 (No. 6)	0.141	0.003	0.013	0.047	0.031	0.253
0.164 (No. 8)	0.168	0.004	0.014	0.055	0.040	0.296
0.190 (No. 10)	0.194	0.004	0.015	0.062	0.047	0.337
0.216 (No. 12)	0.221	0.005	0.016	0.070	0.056	0.380
1/4	0.255	0.005	0.017	0.109	0.062	0.493
5/16	0.319	0.006	0.020	0.125	0.078	0.591
3/8	0.382	0.007	0.023	0.141	0.094	0.688
7/16	0.446	0.008	0.026	0.156	0.109	0.784
1/2	0.509	0.009	0.029	0.171	0.125	0.879
9/16	0.573	0.010	0.032	0.188	0.141	0.979
5/8	0.636	0.011	0.035	0.203	0.156	1.086
11/16	0.700	0.012	0.038	0.219	0.172	1.184
3/4	0.763	0.013	0.041	0.234	0.188	1.279
13/16	0.827	0.014	0.044	0.250	0.203	1.377
7/8	0.890	0.015	0.047	0.266	0.219	1.474
15/16	0.954	0.016	0.050	0.281	0.234	1.570
1	1.017	0.017	0.053	0.297	0.250	1.672
1 1/16	1.081	0.018	0.056	0.312	0.266	1.768
1 1/8	1.144	0.019	0.059	0.328	0.281	1.865
1 3/16	1.208	0.020	0.062	0.344	0.297	1.963
1 1/4	1.271	0.021	0.065	0.359	0.312	2.058
1 5/16	1.335	0.022	0.068	0.375	0.328	2.156
1 3/8	1.398	0.023	0.071	0.391	0.344	2.253
1 7/16	1.462	0.024	0.074	0.406	0.359	2.349
1 1/2	1.525	0.025	0.077	0.422	0.375	2.446

[a] All dimensions are given in inches.
For increased thickness due to taper, see paragraph covering washer section.
[b] The maximum outside diameters specified allow for the commercial tolerances on cold-drawn wire and hot-rolled rod.



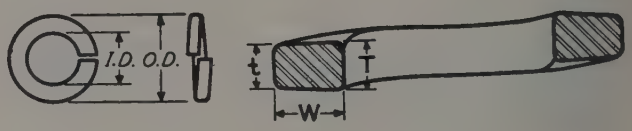


TABLE 4—*Dimensions of Heavy Spring Lock Washers*[a]

NOMINAL SIZE	INSIDE DIAMETER	CLEARANCE OF NOMINAL BOLT SIZE		WASHER SECTIONS, MIN		OUTSIDE DIAM
	Min	Min	Max	Width, w	Thickness, $\frac{T+t}{2}$	Max[b]
0.086 (No. 2)	0.088	0.002	0.011	0.040	0.025	0.185
0.099 (No. 3)	0.102	0.002	0.011	0.047	0.031	0.212
0.112 (No. 4)	0.115	0.003	0.012	0.047	0.031	0.226
0.125 (No. 5)	0.128	0.003	0.012	0.055	0.040	0.255
0.138 (No. 6)	0.141	0.003	0.013	0.055	0.040	0.269
0.164 (No. 8)	0.168	0.004	0.014	0.062	0.047	0.310
0.190 (No. 10)	0.194	0.004	0.015	0.070	0.056	0.353
0.216 (No. 12)	0.221	0.005	0.016	0.077	0.063	0.394
1/4	0.255	0.005	0.017	0.110	0.077	0.495
5/16	0.319	0.006	0.020	0.130	0.097	0.601
3/8	0.382	0.007	0.023	0.145	0.115	0.696
7/16	0.446	0.008	0.026	0.160	0.133	0.792
1/2	0.509	0.009	0.029	0.176	0.151	0.889
9/16	0.573	0.010	0.032	0.193	0.170	0.989
5/8	0.636	0.011	0.035	0.210	0.189	1.100
11/16	0.700	0.012	0.038	0.227	0.207	1.200
3/4	0.763	0.013	0.041	0.244	0.226	1.299
13/16	0.827	0.014	0.044	0.262	0.246	1.401
7/8	0.890	0.015	0.047	0.281	0.266	1.504
15/16	0.954	0.016	0.050	0.298	0.284	1.604
1	1.017	0.017	0.053	0.319	0.306	1.716
1 1/16	1.081	0.018	0.056	0.338	0.326	1.820
1 1/8	1.144	0.019	0.059	0.356	0.345	1.921
1 3/16	1.208	0.020	0.062	0.373	0.364	2.021
1 1/4	1.271	0.021	0.065	0.393	0.384	2.126
1 5/16	1.335	0.022	0.068	0.410	0.403	2.226
1 3/8	1.398	0.023	0.071	0.427	0.422	2.325
1 7/16	1.462	0.024	0.074	0.442	0.440	2.421
1 1/2	1.525	0.025	0.077	0.458	0.458	2.518

[a] All dimensions are given in inches.
For increased thickness due to taper, see paragraph covering washer section.
[b] The maximum outside diameters specified allow for the commercial tolerances on cold-drawn wire and hot-rolled rod.

TABLE 5—*Dimensions of Extra-Heavy Spring Lock Washers*[a]

NOMINAL SIZE	INSIDE DIAMETER	CLEARANCE OF NOMINAL BOLT SIZE		WASHER SECTIONS, MIN		OUTSIDE DIAM
	Min	Min	Max	Width, w	Thickness, $\frac{T+t}{2}$	Max[b]
0.086 (No. 2)	0.088	0.002	0.011	0.053	0.027	0.211
0.099 (No. 3)	0.102	0.002	0.011	0.062	0.034	0.242
0.112 (No. 4)	0.115	0.003	0.012	0.062	0.034	0.256
0.125 (No. 5)	0.128	0.003	0.012	0.079	0.045	0.303
0.138 (No. 6)	0.141	0.003	0.013	0.079	0.045	0.317
0.164 (No. 8)	0.168	0.004	0.014	0.096	0.057	0.378
0.190 (No. 10)	0.194	0.004	0.015	0.112	0.068	0.437
0.216 (No. 12)	0.221	0.005	0.016	0.130	0.080	0.500
1/4	0.255	0.005	0.017	0.132	0.084	0.539
5/16	0.319	0.006	0.020	0.143	0.108	0.627
3/8	0.382	0.007	0.023	0.170	0.123	0.746
7/16	0.446	0.008	0.026	0.186	0.143	0.844
1/2	0.509	0.009	0.029	0.204	0.162	0.945
9/16	0.573	0.010	0.032	0.223	0.182	1.049
5/8	0.636	0.011	0.035	0.242	0.202	1.164
11/16	0.700	0.012	0.038	0.260	0.221	1.266
3/4	0.763	0.013	0.041	0.279	0.241	1.369
13/16	0.827	0.014	0.044	0.298	0.261	1.473
7/8	0.890	0.015	0.047	0.322	0.285	1.586
15/16	0.954	0.016	0.050	0.345	0.308	1.698
1	1.017	0.017	0.053	0.366	0.330	1.810
1 1/16	1.081	0.018	0.056	0.389	0.352	1.922
1 1/8	1.144	0.019	0.059	0.411	0.375	2.031
1 3/16	1.208	0.020	0.062	0.431	0.396	2.137
1 1/4	1.271	0.021	0.065	0.452	0.417	2.244
1 5/16	1.335	0.022	0.068	0.472	0.438	2.350
1 3/8	1.398	0.023	0.071	0.491	0.458	2.453
1 7/16	1.462	0.024	0.074	0.509	0.478	2.555
1 1/2	1.525	0.025	0.077	0.526	0.496	2.654

[a] All dimensions are given in inches.
For increased thickness due to taper, see paragraph covering washer section.
[b] The maximum outside diameters specified allow for the commercial tolerances on cold-drawn wire and hot-rolled rod.

Carbon-Steel Spring Lock Washers—The following additional requirements peculiar to carbon-steel spring lock washers supplement the requirements set forth in the General Specifications applying to all spring lock washers.

Dimensions—Carbon-steel washers are available in the four series specified in Tables 2 to 5: light, medium, heavy, and extra heavy.

When carbon-steel spring lock washers are to be hot-dipped galvanized for use with hot-dipped galvanized bolts or screws, they shall be coiled to limits 0.020 in excess of those specified in Tables 2 to 5 for minimum inside diameter, minimum and maximum clearance, and maximum outside diameter. Galvanized lock washers under ¼-in. nominal size are impractical.

Material and Hardness—Washers shall be made from carbon steel fabricated and heat-treated to a Rockwell hardness of 45–53 C scale. They shall be ground down to remove decarburization before testing hardness. They shall also meet the test requirements of this Standard. Galvanized lock washers shall have a Rockwell hardness of 45–53 C scale before galvanizing.

Finish—Plated washers shall be baked 4 hr at 400 F as soon as practicable after plating in order to relieve hydrogen or acid embrittlement. If washers so treated fail to meet the prescribed tests, the baking time or the temperature or both shall be increased.

Stainless-Steel Spring Lock Washers, Type 302—The following requirements peculiar to stainless-steel spring lock washers supplement the requirements set forth in the General Specifications applying to all spring lock washers.

Dimensions—Stainless-steel spring lock washers, Type 302, are available in the light and medium series specified in Tables 2 and 3.

Material and Hardness—Washers shall be made from stainless steel, ASTM A 313, AISI Type 302. They shall be fabricated and cold worked to a Rockwell hardness of 35–43 C scale.

Stainless-Steel Spring Lock Washers, Type 420—The following requirements peculiar to stainless-steel spring lock washer supplement the requirements set forth in the General Specifications applying to all spring lock washers.

Dimensions—Stainless-steel spring lock washers, Type 420, are available in the light and medium series specified in Tables 2 and 3.

Material and Hardness—Washers shall be made from stainless steel, AISI Type 420. After coiling they shall be heat-treated by quenching in air or oil as indicated by proportions of the washer section and tempering at a temperature not to exceed 800 F to a Rockwell hardness of 43–53 C scale.

Aluminum-Zinc Alloy Spring Lock Washers—The following additional requirements peculiar to aluminum-zinc alloy spring lock washers supplement the requirements set forth in the General Specifications applying to all spring lock washers.

Dimensions—Aluminum-zinc alloy spring lock washers are available in the medium series given in Table 3.

Material and Hardness—Washers shall be made from aluminum-zinc alloy conforming to ASTM Specification B 211, Alloy ZG42, or a similar alloy of equivalent physical properties.

The washers shall receive a solution and precipitation heat-treatment resulting in a Rockwell hardness of 75–97 B scale or a minimum tensile strength of 77,000 psi.

Tensile-test pieces of keystone wire heat-treated with the lock washers they represent shall be furnished upon agreement between the purchaser and manufacturer.

A typical composition, given in %, of the material is as follows:

Copper	1.2 to 2.0
Iron, max	0.70
Silicon, max	0.50
Manganese, max	0.30
Magnesium	2.1 to 2.9
Zinc	5.1 to 6.1
Chromium	0.15 to 0.40
Titanium, max	0.20
Other elements, max, each	0.05
Other elements, max, total	0.15
Aluminum	remainder

Phosphor-Bronze Spring Lock Washers—The following requirements peculiar to phosphor-bronze spring lock washers supplement the requirements set forth in the General Specifications applying to all spring lock washers.

Material and Hardness—Washers shall be made from phosphor bronze conforming to ASTM Specification B 159, Grade A. They shall be fabricated and cold worked to a minimum Rockwell hardness of 90 B scale.

Dimensions—Phosphor-bronze spring lock washers are available in the light and medium series specified in Tables 2 and 3.

Silicon-Bronze Spring Lock Washers—The following requirements peculiar to silicon-bronze spring lock washers supplement the requirements set forth in the General Specifications applying to all spring lock washers.

Dimensions—Silicon-bronze spring lock washers are avilable in the light and medium series specified in Tables 2 and 3.

Material and Hardness—Washers shall be made from silicon bronze conforming to ASTM Specification B 99, Type B. They shall be fabricated and cold worked to a minimum Rockwell hardness of 90 B scale.

K-Monel Spring Lock Washers—The following requirements peculiar to K-Monel spring lock washers supplement the requirements set forth in the General Specifications applying to all spring lock washers.

Dimensions—K-Monel spring lock washers are avilable in the light and medium series specified in Tables 2 and 3.

Material and Hardness—Washers shall be made from K-Monel conforming to Federal Specification QQ-N-286 or Navy Specification 46-N-5 or both. The washers shall be manufactured from cold-worked material and subsequently age hardened to a Rockwell hardness of 33–40 C scale or a minimum tensile strength of 155,000 psi. The chemical composition, given in %, of the material shall be as follows:

Nickel	63.00 to 70.00
Aluminum	2.00 to 4.00
Iron, max	2.00
Manganese, max	1.00
Silicon, max	0.50
Carbon, max	0.25
Other metals, max	1.00
Copper	remainder

Tooth Lock Washers

Use and Application—Use and application of tooth lock washers are described in Introduction.

(*Text continued after Table 9.*)

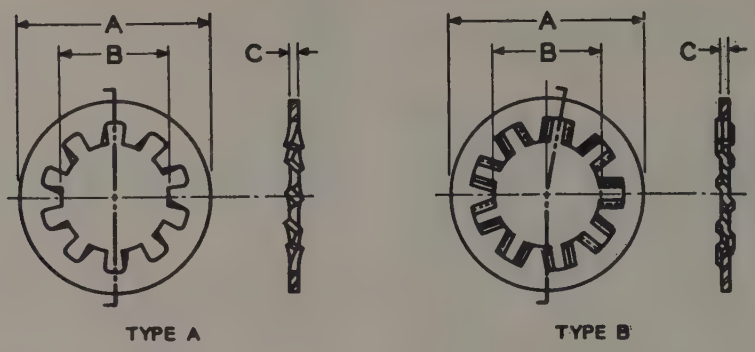


TABLE 6—*Internal-Tooth Lock Washers*[a]

	SIZE	#2	#3	#4	#5	#6	#8	#10	#12	¼	5/16	3/8
A	Max	0.200	0.232	0.270	0.280	0.295	0.340	0.381	0.410	0.478	0.610	0.692
	Min	0.175	0.215	0.255	0.245	0.275	0.325	0.365	0.394	0.460	0.594	0.670
B	Max	0.095	0.109	0.123	0.136	0.150	0.176	0.204	0.231	0.267	0.332	0.398
	Min	0.089	0.102	0.115	0.129	0.141	0.168	0.195	0.221	0.256	0.320	0.384
C	Max	0.015	0.019	0.019	0.021	0.021	0.023	0.025	0.025	0.028	0.034	0.040
	Min	0.010	0.012	0.015	0.017	0.017	0.018	0.020	0.020	0.023	0.028	0.032

	SIZE	7/16	½	9/16	5/8	11/16	¾	13/16	⅞	1	1⅛	1¼
A	Max	0.789	0.900	0.985	1.071	1.166	1.245	1.315	1.410	1.637	1.830	1.975
	Min	0.740	0.867	0.957	1.045	1.130	1.220	1.290	1.364	1.590	1.799	1.921
B	Max	0.464	0.530	0.596	0.663	0.728	0.795	0.861	0.927	1.060	1.192	1.325
	Min	0.448	0.512	0.576	0.640	0.704	0.769	0.832	0.894	1.019	1.144	1.275
C	Max	0.040	0.045	0.045	0.050	0.050	0.055	0.055	0.060	0.067	0.067	0.067
	Min	0.032	0.037	0.037	0.042	0.042	0.047	0.047	0.052	0.059	0.059	0.059

[a] All dimensions are given in inches.

TABLE 7—*Heavy Internal-Tooth Lock Washers*[a]

	SIZE	¼	5/16	3/8	7/16	½	9/16	5/8	¾	⅞
A	Max	0.536	0.607	0.748	0.858	0.924	1.034	1.135	1.265	1.447
	Min	0.500	0.590	0.700	0.800	0.880	0.990	1.100	1.240	1.400
B	Max	0.267	0.332	0.398	0.464	0.530	0.596	0.663	0.795	0.927
	Min	0.256	0.320	0.384	0.448	0.512	0.576	0.640	0.768	0.894
C	Max	0.045	0.050	0.050	0.067	0.067	0.067	0.067	0.084	0.084
	Min	0.035	0.040	0.042	0.050	0.055	0.055	0.059	0.070	0.075

[a] All dimensions are given in inches.

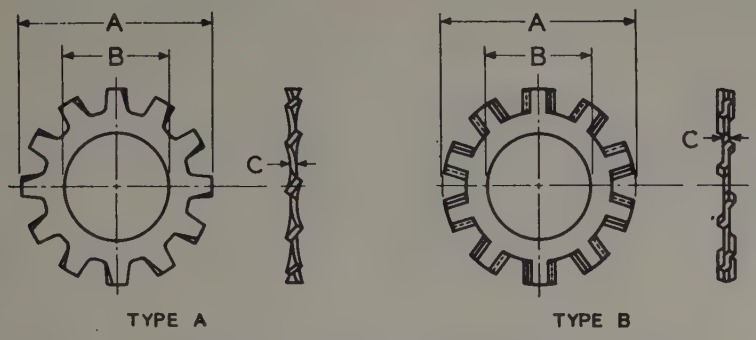


TABLE 8—*External-Tooth Lock Washers*[a]

	SIZE	#2	#3	#4	#5	#6	#8	#10	#12	¼	5/16	3/8
A	Max	—	—	0.290	—	0.320	0.381	0.410	0.475	0.510	0.610	0.694
	Min	—	—	0.275	—	0.305	0.365	0.395	0.460	0.494	0.588	0.670
B	Max	—	—	0.123	—	0.150	0.176	0.204	0.231	0.267	0.332	0.398
	Min	—	—	0.115	—	0.141	0.168	0.195	0.221	0.256	0.320	0.384
C	Max	—	—	0.019	—	0.022	0.023	0.025	0.028	0.028	0.034	0.040
	Min	—	—	0.015	—	0.016	0.018	0.020	0.023	0.023	0.028	0.032

	SIZE	7/16	½	9/16	5/8	11/16	¾	13/16	7/8	1	1⅛	1¼
A	Max	0.760	0.900	0.985	1.070	1.155	1.260	1.315	1.410	1.620	—	—
	Min	0.740	0.880	0.960	1.045	1.130	1.220	1.290	1.380	1.590	—	—
B	Max	0.464	0.530	0.596	0.663	0.728	0.795	0.861	0.927	1.060	—	—
	Min	0.448	0.513	0.576	0.641	0.704	0.768	0.833	0.897	1.025	—	—
C	Max	0.040	0.045	0.045	0.050	0.050	0.055	0.055	0.060	0.067	—	—
	Min	0.032	0.037	0.037	0.042	0.042	0.047	0.047	0.052	0.059	—	—

[a] All dimensions are given in inches.

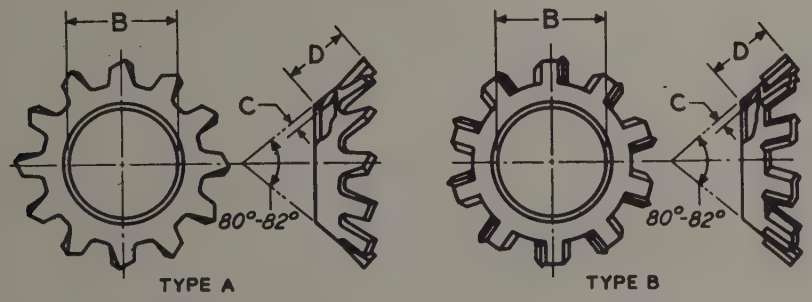


TABLE 9—*Countersunk External-Tooth Lock Washers*

	SIZE	#4	#6	#8	#10	#12	¼	#16	5/16	3/8	7/16	½
B	Max	0.123	0.150	0.177	0.205	0.231	0.267	0.287	0.333	0.398	0.463	0.529
	Min	0.113	0.140	0.167	0.195	0.220	0.255	0.273	0.318	0.383	0.448	0.512
C	Max	0.019	0.021	0.021	0.025	0.025	0.025	0.028	0.028	0.034	0.045	0.045
	Min	0.015	0.017	0.017	0.020	0.020	0.020	0.023	0.023	0.028	0.037	0.037
D	Max	0.065	0.092	0.105	0.099	0.128	0.128	0.147	0.192	0.255	0.270	0.304
	Min	0.050	0.082	0.088	0.083	0.118	0.113	0.137	0.165	0.242	0.260	0.294
E[a]	Approx OD	0.213	0.289	0.322	0.354	0.421	0.454	0.505	0.599	0.765	0.867	0.976

[a] For reference purposes only.

Dimensions—Dimensions of internal-tooth lock washers, heavy internal-tooth lock washers, external-tooth lock washers, countersunk external-tooth lock washers, and internal-external-tooth lock washers are specified in Tables 6 to 10.

Manufacturing Detail—The number of teeth, the length of the teeth, the width of the rim, and the thickness of the washer over the teeth (free height) shall be optional with the manufacturer, with the provision, however, that the projection of the teeth on both sides of the washer shall be uniform within a tolerance equal to one half of the projection on one side. Washers shall be symmetrical in shape and free from defects which might affect their serviceability.

Material and Hardness—Washers shall be made from carbon steel, fabricated and heat-treated to a Rockwell hardness of 40–50 C scale or equivalent. It is recommended, however, that the lighter, more sensitive depth reading Rockwell A scale be used when testing washers of thin section. Decarburization shall be removed before testing hardness.

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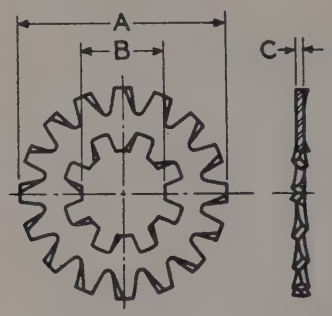
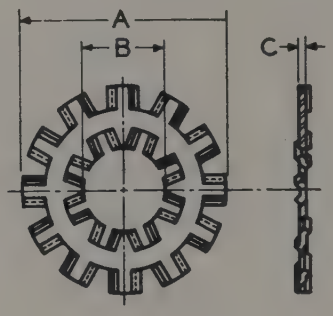


TYPE A



TYPE B

TABLE 10—*Internal-External-Tooth Lock Washers*[a]

SIZE	A		B		C		SIZE	A		B		C	
	Outside diameter		Inside diameter		Thickness			Outside diameter		Inside diameter		Thickness	
	Max	Min	Max	Min	Max	Min		Max	Min	Max	Min	Max	Min
	0.475	0.460			0.021	0.017		0.900	0.865			0.040	0.032
#4	0.510	0.495	0.123	0.115	0.021	0.017	5/16	0.985	0.965	0.332	0.320	0.045	0.037
	0.610	0.580			0.021	0.017		1.070	1.045			0.050	0.042
								1.155	1.130			0.050	0.042
	0.510	0.495			0.028	0.023							
#6	0.610	0.580	0.150	0.141	0.028	0.023		0.985	0.965			0.045	0.037
	0.690	0.670			0.028	0.023	3/8	1.070	1.045	0.398	0.384	0.050	0.042
								1.155	1.130			0.050	0.042
	0.610	0.580			0.034	0.028		1.260	1.220			0.050	0.042
#8	0.690	0.670	0.176	0.168	0.034	0.028							
	0.760	0.740			0.034	0.028		1.070	1.045			0.050	0.042
							7/16	1.155	1.130	0.464	0.448	0.050	0.042
								1.260	1.220			0.055	0.047
	0.610	0.580			0.034	0.028		1.315	1.290			0.055	0.047
#10	0.690	0.670	0.204	0.195	0.040	0.032							
	0.760	0.740			0.040	0.032		1.260	1.220			0.055	0.047
	0.900	0.880			0.040	0.032	1/2	1.315	1.290	0.530	0.512	0.055	0.047
								1.410	1.380			0.060	0.052
	0.690	0.670			0.040	0.032		1.620	1.590			0.067	0.059
#12	0.760	0.725	0.231	0.221	0.040	0.032							
	0.900	0.880			0.040	0.032		1.315	1.290			0.055	0.047
	0.985	0.965			0.045	0.037	9/16	1.430	1.380	0.596	0.576	0.060	0.052
								1.620	1.590			0.067	0.059
	0.760	0.725			0.040	0.032		1.830	1.797			0.067	0.059
1/4	0.900	0.880	0.267	0.256	0.040	0.032							
	0.985	0.965			0.045	0.037		1.410	1.380			0.060	0.052
	1.070	1.045			0.045	0.037	5/8	1.620	1.590	0.663	0.640	0.067	0.059
								1.830	1.797			0.067	0.059
								1.975	1.935			0.067	0.059

[a] All dimensions are given in inches.

Finish—Plated washers shall be baked 4 hr at 400 F as soon as practicable after plating in order to relieve hydrogen or acid embrittlement. If washers so treated fail to meet the prescribed tests, the baking time or the temperature or both shall be increased.

Designation—Washers shall be specified or designated by the nominal size, description and type, that is, ¼ in. internal tooth, Type A; 9/16 in. external tooth, Type B; No. 12 internal-external tooth, Type A.

Temper Test—Washers shall be set down or deflected a distance equivalent to one third turn of a coarse-thread nut of corresponding size. The free height of the washer on release shall be at least five sixths of the original free height.

Spread Test—The rim of the lock washer shall be cut or severed with a cold chisel or cutting pliers and the severed ends shall be gripped by pliers or vise and pliers. Separation of the ends in the form of a helix, to a distance equal to the inside diameter of the washer, shall not result in fracture. When the ends are separated a greater distance and the washer fractures, the fracture at the point of fracture shall show a fine grain, and the washer up to the instant of fracture shall deliver a tough springy reaction.

Spring Lock Washer and Machine-Screw Assemblies—*Use and Application*—Use and application of spring lock washer and machine-screw assemblies are described in Introduction.

This Standard applies to slotted-screw assemblies shown in the drawings and to comparable cross-recess-screw assemblies. The screw and washer combinations specified in the dimensional tables are preferred. Screws of any type head, however, may be assembled with the washers specified for screws of the other head types.

Machine Screws—The machine-screw component of the assemblies shall conform to the specifications for machine screws published in SAE Standard for Slotted- and Recessed-Head Screws (ASA B18.6), except (1) that the maximum diameter of the unthreaded portion shall be less than the maximum major diameter of the thread by an amount sufficient to prevent removal of the washer from the screw; and (2) that on screws 2 in. long and shorter, the complete threads shall extend to within two threads of the bearing surface of the washer or closer if practicable.

Spring Lock Washers—Dimensions of the spring lock-washer components of the assemblies are specified in Table 11. The washers shall otherwise conform to the standard for spring lock washers of the materials indicated except for modifications specified in this Standard.

Assembly Detail—Washers shall be coiled so that the free height is approximately twice the thickness of the washer section, which shall be slightly trapezoidal in shape with rounded edges and with the thickness at the inner periphery slightly greater than the thickness at the outer periphery.

The washers shall be assembled on headed screw blanks before the threads are rolled. The inside diameter of the washers shall be of a size which will permit free rotation and yet prevent their disassembly from the screws.

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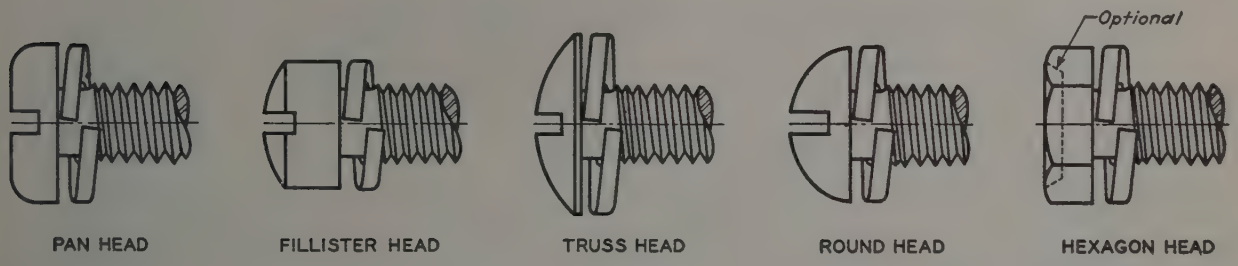


TABLE 11—*Spring Lock Washer and Machine-Screw Assemblies*[a]

SCREW SIZE	PAN-HEAD SCREW			FILLISTER-HEAD SCREW			TRUSS-HEAD SCREW			ROUND-HEAD SCREW			HEXAGON-HEAD SCREW		
	Washer thickness	Washer outside diameter		Washer thickness	Washer outside diameter		Washer thickness	Washer outside diameter		Washer thickness	Washer outside diameter		Washer thickness	Washer outside diameter	
	Min	Min	Max	Min	Min	Max	Min	Min	Max	Min	Min	Max	Min	Min	Max
#4	0.031	0.195	0.208	0.020	0.171	0.184	0.034	0.225	0.238	0.031	0.195	0.208	0.020	0.171	0.184
#5	0.031	0.207	0.220	0.020	0.183	0.196	0.031	0.299	0.312	0.034	0.237	0.250	0.020	0.183	0.196
#6	0.034	0.248	0.261	0.031	0.218	0.231	0.031	0.310	0.323	0.034	0.248	0.261	0.031	0.218	0.231
#8	0.031	0.305	0.319	0.031	0.243	0.257	0.047	0.367	0.381	0.031	0.305	0.319	0.031	0.243	0.257
#10	0.047	0.359	0.373	0.040	0.283	0.297	0.047	0.423	0.437	0.047	0.359	0.373	0.047	0.297	0.311
#12	0.062	0.414	0.429	0.047	0.320	0.335	0.070	0.468	0.483	0.047	0.382	0.397	0.047	0.320	0.335
1/4	0.062	0.480	0.496	0.063	0.384	0.400	0.078	0.542	0.558	0.062	0.448	0.464	0.062	0.448	0.464
5/16	0.078	0.602	0.618	0.062	0.508	0.524	—	—	—	0.070	0.562	0.578	0.078	0.540	0.556
3/8	0.093	0.727	0.743	0.062	0.603	0.619	—	—	—	0.093	0.695	0.711	0.094	0.635	0.651

[a] All dimensions are given in inches.

External-Tooth Lock Washer and Machine-Screw Assemblies—*Use and Application*—Use and application of external-tooth lock washer and machine-screw assemblies are described in Introduction.

This Standard applies to slotted-screw assemblies shown in the drawings and to comparable cross-recess-screw assemblies.

Machine Screws—The machine-screw component of the assemblies shall conform to the standard for machine screws published in SAE Standard for Slotted- and Recessed-Head Screws (ASA B18.6), except (1) that the maximum diameter of the unthreaded portion shall be less than the maximum major diameter of the thread by an amount sufficient to prevent disassembly of the washer from the screw and (2) that on screws 2 in. long and shorter, the complete threads shall extend to within two threads of the bearing surface of the washer or closer if practicable.

Tooth Lock Washers—Dimensions of the tooth lock-washer components of the assemblies are given in Table 12. Extrusion of a slight collar at the inside diameter of the countersunk washers for flat- and oval-head screws is optional with manufacturers. The washers shall otherwise conform to the standard for tooth lock washers except for modifications specified in this Standard.

Assembly Detail—Washers shall be assembled on headed screw blanks before the threads are rolled, the inside diameter of the washers being of a size which will permit free rotation and yet prevent their disassembly from the screws after the threads are rolled.

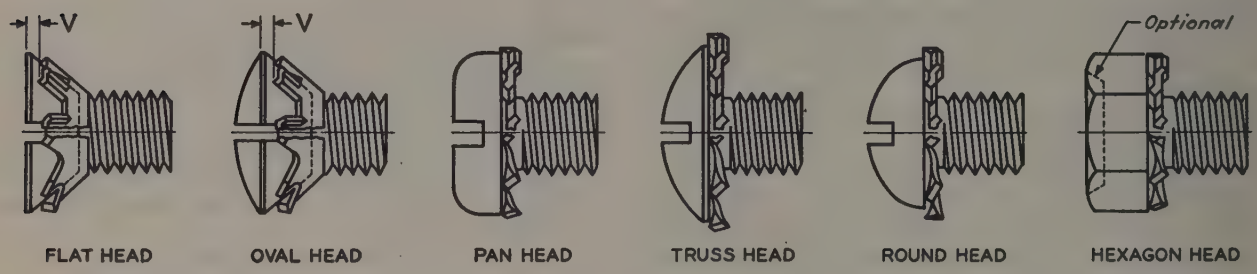


TABLE 12—*Tooth Lock Washer and Machine-Screw Assemblies*[a]

SCREW SIZE	FLAT- AND OVAL-HEAD SCREWS			PAN-HEAD SCREW				TRUSS-HEAD SCREW				ROUND-HEAD SCREW				HEXAGON-HEAD SCREW			
	Washer thickness		*V* Flush with minus tolerance of	Washer thickness		Washer outside diameter		Washer thickness		Washer outside diameter		Washer thickness		Washer outside diameter		Washer thickness		Washer outside diameter	
	Max	Min		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
#4	—	—	—	0.020	0.012	0.230	0.220	0.020	0.014	0.255	0.245	0.020	0.012	0.230	0.220	0.020	0.014	0.230	0.220
#5	—	—	—	0.020	0.014	0.255	0.245	0.020	0.014	0.285	0.270	0.020	0.014	0.255	0.245	0.020	0.016	0.255	0.245
#6	0.020	0.016	0.026	0.020	0.014	0.285	0.270	0.022	0.016	0.320	0.305	0.020	0.014	0.285	0.270	0.020	0.016	0.285	0.270
#8	0.020	0.016	0.030	0.023	0.018	0.320	0.305	0.022	0.016	0.381	0.365	0.023	0.018	0.320	0.305	0.023	0.018	0.320	0.305
#10	0.025	0.019	0.036	0.024	0.018	0.381	0.365	0.027	0.020	0.475	0.460	0.024	0.018	0.381	0.365	0.025	0.020	0.381	0.365
#12	0.025	0.019	0.041	0.027	0.020	0.410	0.395	0.028	0.023	0.510	0.494	0.027	0.020	0.410	0.395	0.027	0.020	0.410	0.395
1/4	0.025	0.019	0.047	0.028	0.023	0.510	0.494	0.028	0.023	0.590	0.567	0.028	0.023	0.475	0.460	0.028	0.023	0.475	0.460
5/16	0.028	0.023	0.060	0.034	0.028	0.610	0.588	—	—	—	—	0.034	0.028	0.610	0.588	0.034	0.028	0.590	0.567
3/8	0.034	0.028	0.072	0.040	0.032	0.760	0.740	—	—	—	—	0.040	0.032	0.695	0.680	0.040	0.032	0.660	0.640

[a] All dimensions are given in inches.
Type A tooth lock washer shown below the centerline. Type B tooth lock washer shown above the centerline.

Ball Joints

SAE Standard

Report of Miscellaneous Division approved March 1920 and last revised by Parts and Fittings Technical Committee November 1948.

Defects—Ball joints must be free from burrs, loose scale, sharp edges, and all other defects which might affect their serviceability.

Threads—Threads are to be American Standard, NS, Class 2.

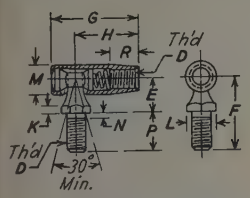


FIG. 1—TYPE A
Nonadjustable end plug with spring

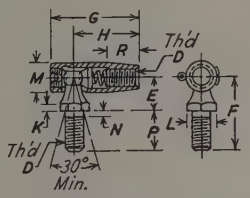


FIG. 2—TYPE B
Adjustable end plug with spring

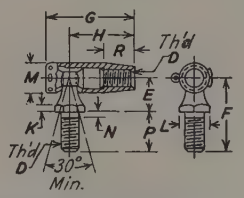


FIG. 3—TYPE C
Adjustable end plug without spring

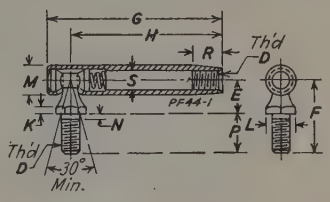


FIG. 4—TYPE A—LONG

TABLE 1a—*Dimensions for Types A, B, C, and A—Long Ball Joints*

THREAD SIZE, *D*	TYPES A, B, AND C							TYPE A—LONG			
	No. 10–32	No. 12–32	¼–28	5/16–24	3/8–24	7/16–20	½–20	No. 10–32	No. 12–32	¼–28	5/16–24
Height, *E*	7/16	7/16	15/32	17/32	11/16	7/8	7/8	7/16	7/16	15/32	17/32
Overall height, *F*	7/8	7/8	1 1/32	1 7/32	1 9/16	2	2	7/8	7/8	1 1/32	1 7/32
Overall length, *G*	1 1/4	1 1/4	1 3/8	1 9/16	1 15/16	2 5/8	2 5/8	1 13/16	1 13/16	2 1/4	2 3/8
Length, *H*	7/8	7/8	31/32	1 1/8	1 3/8	1 15/16	1 15/16	1 1/2	1 1/2	1 13/16	1 15/16
Hex thickness, *K*	1/8	1/8	1/8	5/32	3/16	1/4	1/4	1/8	1/8	1/8	5/32
Hex width, *L*	5/16	5/16	3/8	7/16	1/2	5/8	5/8	5/16	5/16	3/8	7/16
Body diameter, *M*	3/8	3/8	7/16	1/2	5/8	3/4	3/4	3/8	3/8	7/16	1/2
Unthreaded length, *N*	1/16	1/16	1/16	3/32	3/32	1/8	1/8	1/16	1/16	1/16	3/32
Shank length, *P*	7/16	7/16	9/16	11/16	7/8	1 1/8	1 1/8	7/16	7/16	9/16	11/16
Tap depth, *R*	7/16	7/16	1/2	9/16	3/4	1	1	9/16	9/16	7/8	1
Hole diameter, *S*	—	—	—	—	—	—	—	13/64	15/64	17/64	21/64
Stud ball diameter (not intended for inspection) Max	0.255	0.255	0.305	0.350	0.424	0.555	0.555	—	—	—	—
Stud ball diameter (not intended for inspection) Min	0.250	0.250	0.300	0.345	0.419	0.550	0.550	—	—	—	—

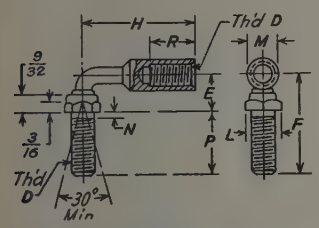


FIG. 5—TYPE D—SINGLE BEND
Not recommended for tension or severe vibration application

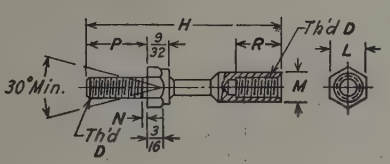


FIG. 6—TYPE D—STRAIGHT
Not recommended for tension or severe vibration application

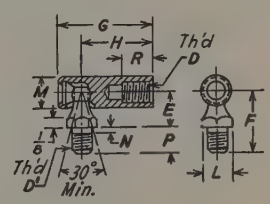


FIG. 7—TYPE G
Nonadjustable end plug without spring or bottom insert

TABLE 1b—*Dimensions for Types D and G Ball Joints*

THREAD SIZE, *D*	TYPE *D*—SINGLE BEND						TYPE D—STRAIGHT					TYPE G			
	No. 10–32	No. 10–32	No. 12–24	No. 12–32	¼–28	5/16–24	No. 10–32	No. 12–24	No. 12–32	¼–28	5/16–24	No. 8–32	No. 10–32	¼–28	5/16–24
Thread size, *D'*	—	—	—	—	—	—	—	—	—	—	—	10–32	10–32	¼–28	5/16–24
Height, *E*	17/32	17/32	17/32	17/32	9/16	11/16	—	—	—	—	—	11/32	7/16	7/16	1/2
Overall height, *F*	31/32	31/32	1 3/32	1 5/32	1 1/8	1 3/8	—	—	—	—	—	1 1/16	7/8	7/8	1
Overall length, *G*	—	—	—	—	—	—	—	—	—	—	—	7/8	1 3/16	1 3/16	1 5/16
Length, *H*	25/32	1 1/32	1 1/32	1 1/32	1 1/16	1 5/16	2 1/32	2 5/16	2 1/32	2 3/32	2 19/32	1 1/16	1 5/16	1 5/16	1 1/16
Hex width, *L*	3/8	3/8	3/8	3/8	7/16	9/16	3/8	3/8	3/8	7/16	9/16	1/4	5/16	5/16	3/8
Body diameter, *M*	9/32	9/32	9/32	9/32	5/16	7/16	9/32	9/32	9/32	5/16	7/16	1/4	5/16	11/32	13/32
Unthreaded length, *N*	1/16	1/16	1/16	1/16	1/16	3/32	1/16	1/16	1/16	1/16	3/32	1/16	3/64	3/64	1/16
Shank length, *P*	7/16	7/16	9/16	9/16	9/16	11/16	9/16	1 1/16	9/16	9/16	11/16	9/32	7/16	7/16	1/2
Tap depth, *R*	3/8	1/2	1/2	1/2	9/16	11/16	1/2	1/2	1/2	9/16	11/16	7/16	7/16	7/16	9/16

Ball Studs and Tie-Rod Sockets

SAE Standard

Report of Parts and Fittings Division approved August 1922 and last revised by Parts and Fittings Technical Committee January 1951.

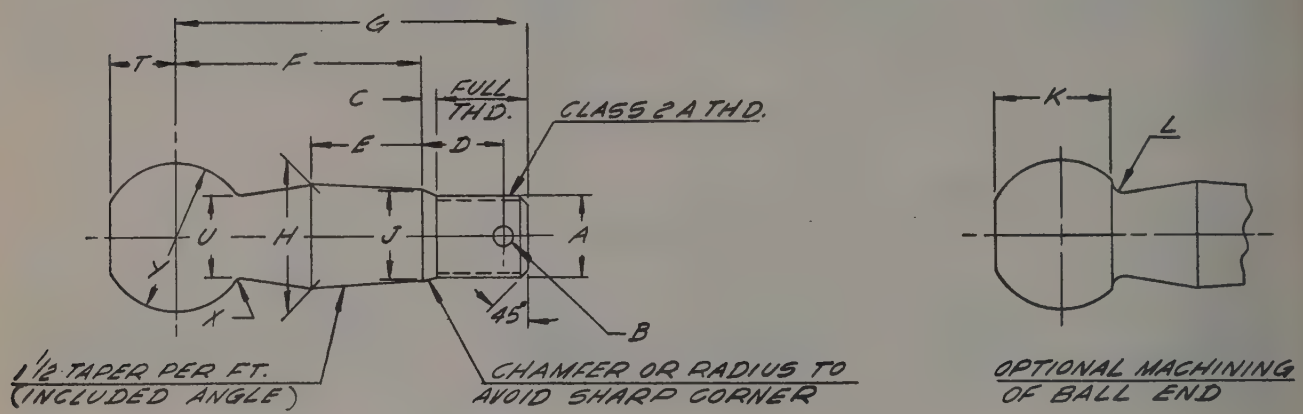
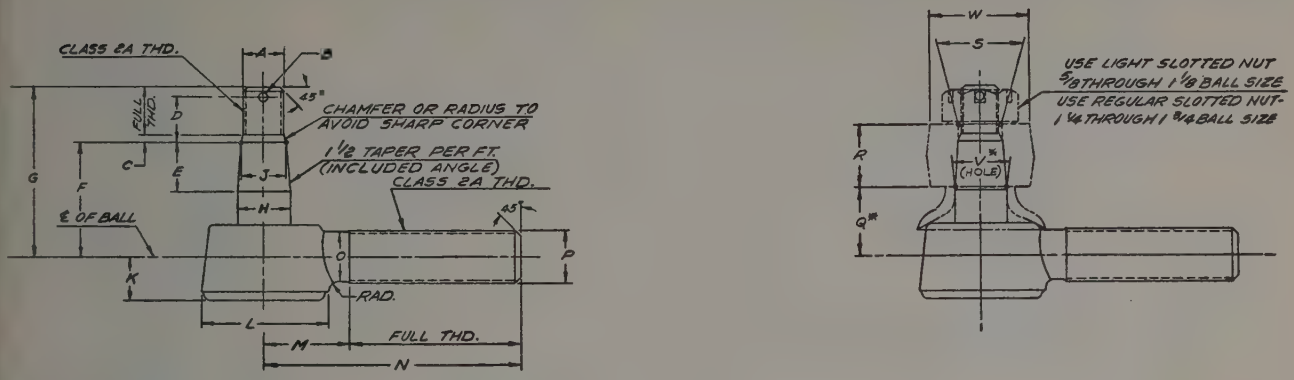


FIG. 1—BALL STUD

TABLE 1—*Ball-Stud Dimensions*

BALL DIAM, *Y*, +0.000 −0.004	*A*	*B*	*C*, MAX	*D*, ±0.010	*E*	*F*	*G*	*H*, REF	*J*, ±0.002	*K*	*L*	*T*	*U*	*X*
5/8	3/8–24	1/8	5/64	25/64	13/32	1 1/16	1 39/64	15/32	0.418	31/64	3/64	9/32	11/32	3/64
3/4	7/16–20	1/8	5/64	7/16	29/64	1 13/64	1 51/64	35/64	0.490	37/64	3/64	5/16	13/32	3/64
7/8	1/2–20	1/8	3/32	31/64	33/64	1 23/64	2 1/64	5/8	0.560	11/16	1/16	3/8	15/32	1/16
1	9/16–18	5/32	3/32	37/64	23/32	1 5/8	2 25/64	45/64	0.613	25/32	3/32	7/16	9/16	1/16
1 1/8	5/8–18	5/32	7/64	5/8	27/32	1 7/8	2 11/16	25/32	0.675	7/8	3/32	1/2	5/8	1/16
1 1/4	5/8–18	5/32	7/64	41/64	15/16	2 1/32	2 55/64	7/8	0.758	1	1/8	9/16	11/16	3/32
1 1/2	3/4–16	5/32	7/64	23/32	1 1/8	2 7/16	3 3/8	1 1/32	0.890	15/32	1/8	5/8	13/16	3/32
1 3/4	7/8–14	5/32	5/32	55/64	1 13/32	2 15/16	4 3/64	1 1/4	1.074	1 3/8	5/32	3/4	15/16	1/8

(*Continued on next page.*)



*Before tightening nut

FIG. 2—TIE-ROD SOCKET

TABLE 2—*Dimensions of Tie-Rod Sockets*

EQUIVALENT BALL SIZE	*A*	*B*	*C*, MAX	*D*, ±0.010	*E*	*F*	*G*	*H*, REF	*J*, ±0.002	*K*, MAX	*L*, MAX
5/8	3/8–24	1/8	5/64	25/64	13/32	1 1/16	1 39/64	15/32	0.418	9/16	1 1/4
3/4	7/16–20	1/8	5/64	7/16	29/64	1 13/64	1 51/64	35/64	0.490	5/8	1 1/2
7/8	1/2–20	1/8	3/32	31/64	33/64	1 23/64	2 1/64	5/8	0.560	3/4	1 5/8
1	9/16–18	5/32	3/32	37/64	23/32	1 5/8	2 25/64	45/64	0.613	15/16	1 3/4
1 1/8	5/8–18	5/32	7/64	5/8	27/32	1 7/8	2 11/16	25/32	0.675	1 3/16	2 1/16
1 1/4	5/8–18	5/32	7/64	41/64	15/16	2 1/32	2 55/64	7/8	0.758	1 5/16	2 5/16
1 1/2	3/4–16	5/32	7/64	23/32	1 1/8	2 7/16	3 3/8	1 1/32	0.890	1 7/16	2 5/8
1 3/4	7/8–14	5/32	5/32	55/64	1 13/32	2 15/16	4 3/64	1 1/4	1.074	1 5/8	3 1/4

EQUIVALENT BALL SIZE	*M*	*N*	*O*, MIN	*P*	*Q*[a]	*R*	*S*, ±0.002	*V*[a] REF	*W*	NOMINAL COTTER PIN
5/8	7/8	2 5/8	17/32	9/16–18 PD $\frac{0.5205}{0.5250}$	1 1/16	1/2	0.402	0.465	7/8	3/32 x 1
3/4	1	2 15/16	17/32	9/16–18 PD $\frac{0.5205}{0.5250}$	25/32	9/16	0.473	0.543	1	3/32 x 1
7/8	1 1/16	3 1/8	21/32	1 1/16–18 PD $\frac{0.6455}{0.6500}$	7/8	5/8	0.543	0.621	1 1/8	3/32 x 1 1/8
1	1 3/16	3 3/8	21/32	1 1/16–18 PD $\frac{0.6455}{0.6500}$	15/16	7/8	0.590	0.699	1 1/4	1/8 x 1 1/4
1 1/8	1 5/16	3 7/8	27/32	7/8–18 PD $\frac{0.8329}{0.8375}$	1 1/16	1	0.652	0.777	1 5/16	1/8 x 1 3/8
1 1/4	1 1/2	4 1/4	31/32	1–16 PD $\frac{0.9529}{0.9579}$	1 1/8	1 1/8	0.731	0.871	1 7/16	1/8 x 1 1/2
1 1/2	1 11/16	4 7/8	1 5/64	1 1/8–12 PD $\frac{1.0631}{1.0691}$	1 11/32	1 5/16	0.863	1.027	1 11/16	1/8 x 1 5/8
1 3/4	2	5 3/4	1 13/64	1 1/4–12 PD $\frac{1.1879}{1.1941}$	1 9/16	1 5/8	1.043	1.246	2	1/8 x 1 3/4

[a] Before tightening nut.

Split and Tubular Rivets — SAE Recommended Practice

Report of Parts and Fittings Division approved February 1928 and last revised June 1929.

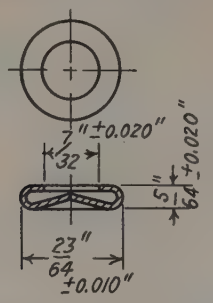


FIG. 1—RIVET CAP FOR USE WITH SPLIT RIVETS AND WROUGHT-IRON TUBULAR RIVETS

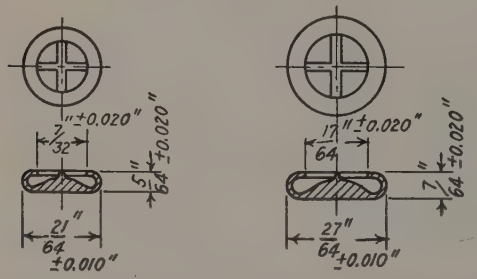


FIG. 2—RIVET CAPS FOR USE WITH STEEL AND BRASS TUBULAR RIVETS

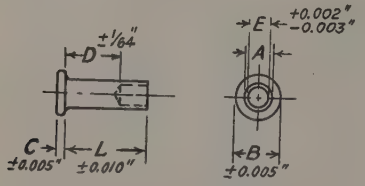


FIG. 3—FLAT-HEAD TUBULAR RIVET

TABLE 1—*Flat-Head Tubular Rivets*

NOMINAL DIAMETER	A	B	C	D	E	L
1/8	0.123 ± 0.003	1/4	0.020	L-1/16	0.086	3/32 to 3/8 by 1/32
9/64	0.145 ± 0.003	5/16	3/64	L-5/32	0.098	3/16 to 5/8 by 1/32
3/16	0.186 ± 0.005	7/16	1/16	L-3/16	0.133	1/4 to 5/8 by 1/32

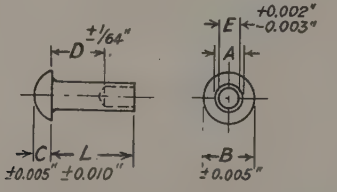


FIG. 4—OVAL-HEAD TUBULAR RIVET

TABLE 2—*Oval-Head Tubular Rivets*

NOMINAL DIAMETER	A	B	C	D	E	L
1/8	0.123 ± 0.003	7/32	1/32	L-1/16	0.086	3/32 to 5/8 by 1/32
9/64	0.145 ± 0.003	5/16	3/64	L-1/8	0.098	3/16 to 5/8 by 1/32
9/64	0.145 ± 0.003	5/16	3/64	L-3/16	0.098	1/4 to 5/8 by 1/32
9/64	0.145 ± 0.003	5/16	3/64	L-1/4	0.098	5/16 to 5/8 by 1/32
3/16	0.186 ± 0.005	3/8	1/16	L-1/8	0.133	3/16 to 3/4 by 1/32
3/16	0.186 ± 0.005	3/8	1/16	L-3/16	0.133	1/4 to 3/4 by 1/32

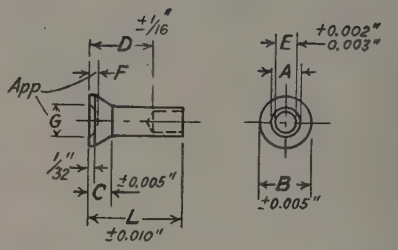


FIG. 5—CUPPED COUNTERSUNK-HEAD TUBULAR RIVET

TABLE 3—*Cupped Countersunk-Head Tubular Rivets*

NOMINAL DIAMETER	A	B	C	D	E	F	G	L
9/64	0.145 ± 0.003	5/16	7/64	L-1/8	0.098	3/64	1/4	9/32 to 5/8 by 1/32
3/16	0.186 ± 0.005	3/8	1/8	L-5/32	0.133	1/16	19/64	9/32 to 5/8 by 1/32

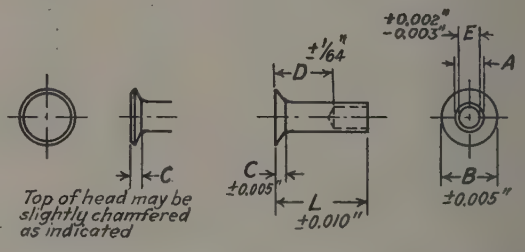


FIG. 6—FLAT COUNTERSUNK-HEAD TUBULAR RIVET

TABLE 4—*Flat Countersunk-Head Tubular Rivets*[a]

NOMINAL DIAMETER	A	B	C	D	E	L
1/8	0.123 ± 0.003	1/4	1/32	L-5/32	0.086	1/4 to 1/2 by 1/32
9/64	0.145 ± 0.003	5/16	3/64	L-1/8	0.098	1/4 to 5/8 by 1/32
9/64	0.145 ± 0.003	5/16	3/64	L-3/16	0.098	1/4 to 5/8 by 1/32
9/64	0.145 ± 0.003	5/16	3/64	drilled to head	0.098	5/16 to 1/2 by 1/32
3/16	0.186 ± 0.005	3/8	3/64	L-1/8	0.133	1/4 to 3/4 by 1/32
3/16	0.186 ± 0.005	3/8	3/64	L-3/16	0.133	1/4 to 3/4 by 1/32
3/16	0.186 ± 0.005	3/8	3/64	drilled to head	0.133	5/16 to 1/2 by 1/32

[a] The above specifications are for steel and brass rivets for a roll clinch; where star clinch or wrought-iron rivet is used, the drill size should be 0.006 in. larger.

(*Continued on next page.*)

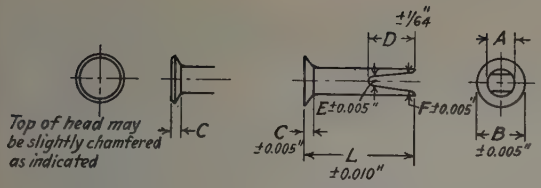


FIG. 7—FLAT COUNTERSUNK-HEAD SPLIT RIVET

TABLE 5—*Flat Countersunk-Head Split Rivets*[a]

NOMINAL DIAMETER	A	B	C	L	D	E	F
1/8	0.122 ±0.005	7/32	1/32	1/4	5/32	0.040	0.047
	0.122 ±0.005	7/32	1/32	5/16	7/32	0.040	0.052
	0.122 ±0.005	7/32	1/32	3/8	9/32	0.040	0.057
	0.122 ±0.005	7/32	1/32	7/16–1/2	5/16	0.040	0.057
3/16	0.190 +0.010 −0.005	7/16	3/64	5/16	7/32	0.065	0.120
	0.190 +0.010 −0.005	7/16	3/64	3/8	9/32	0.065	0.125
	0.190 +0.010 −0.005	7/16	3/64	7/16	5/16	0.065	0.127
	0.190 +0.010 −0.005	7/16	3/64	1/2	3/8	0.065	0.130
9/64	0.146 ±0.005	5/16	3/64	1/4	5/32	0.050	0.060
	0.146 ±0.005	5/16	3/64	5/16	7/32	0.050	0.073
	0.146 ±0.005	5/16	3/64	3/8	9/32	0.050	0.078
	0.146 ±0.005	5/16	3/64	7/16	11/32	0.050	0.081
	0.146 ±0.005	5/16	3/64	1/2	11/32	0.050	0.083
	0.146 ±0.005	5/16	3/64	9/16–3/4	13/32	0.052	0.077
	0.146 ±0.005	3/8	3/64	1/4	5/32	0.050	0.060
	0.146 ±0.005	3/8	3/64	5/16	7/32	0.050	0.073
	0.146 ±0.005	3/8	3/64	3/8	9/32	0.050	0.078
	0.146 ±0.005	3/8	3/64	7/16	11/32	0.050	0.081
	0.146 ±0.005	3/8	3/64	1/2	11/32	0.050	0.083
	0.146 ±0.005	3/8	3/64	9/16–3/4	13/32	0.052	0.077

[a] Lengths increase in 1/16-in. steps.

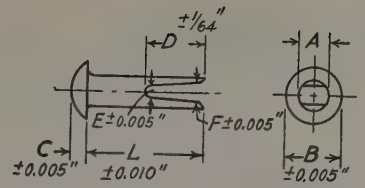


FIG. 8—OVAL-HEAD SPLIT RIVET

TABLE 6—*Oval-Head Split Rivets*[a]

NOMINAL DIAMETER	A	B	C	L	D	E	F
3/32	0.086 ±0.005	9/64	0.025	3/16	5/32	0.030	0.037
	0.086 ±0.005	9/64	0.025	1/4	7/32	0.030	0.039
	0.086 ±0.005	9/64	0.025	5/16	9/32	0.030	0.039
	0.086 ±0.005	9/64	0.025	3/8–1/2	5/16	0.030	0.039
1/8	0.122 ±0.005	7/32	1/32	3/16	5/32	0.040	0.047
	0.122 ±0.005	7/32	1/32	1/4	7/32	0.040	0.052
	0.122 ±0.005	7/32	1/32	5/16	9/32	0.040	0.057
	0.122 ±0.005	7/32	1/32	3/8–3/4	5/16	0.040	0.057
9/64	0.146 ±0.005	5/16	3/64	3/16	5/32	0.050	0.060
	0.146 ±0.005	5/16	3/64	1/4	7/32	0.050	0.073
	0.146 ±0.005	5/16	3/64	5/16	9/32	0.050	0.078
	0.146 ±0.005	5/16	3/64	3/8	11/32	0.050	0.081
	0.146 ±0.005	5/16	3/64	7/16	11/32	0.050	0.083
	0.146 ±0.005	5/16	3/64	1/2–3/4	13/32	0.052	0.077
3/16	0.190 +0.010 −0.005	11/32	1/16	1/4	7/32	0.065	0.120
	0.190 +0.010 −0.005	11/32	1/16	5/16	9/32	0.065	0.125
	0.190 +0.010 −0.005	11/32	1/16	3/8	5/16	0.065	0.127
	0.190 +0.010 −0.005	11/32	1/16	7/16	3/8	0.065	0.130
	0.190 +0.010 −0.005	11/32	1/16	1/2	7/16	0.068	0.133

[a] Lengths increase in 1/16-in. steps.

Rod Ends and Pins

SAE Standard

Report of Miscellaneous Division approved January 1915 and last revised by Parts and Fittings Division January 1945.

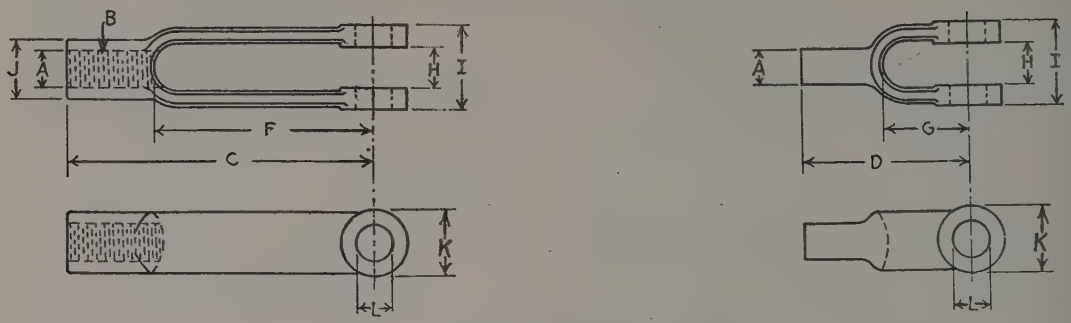


FIG. 1—ADJUSTABLE AND PLAIN YOKES

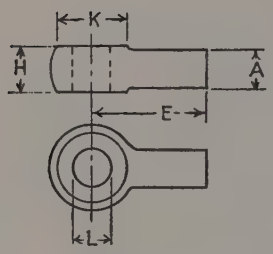


FIG. 2—EYE

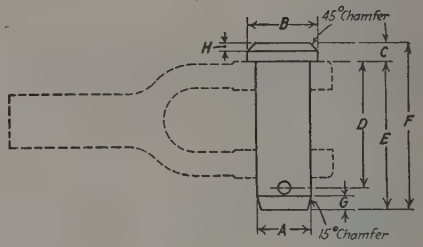


FIG. 3—PIN

TABLE 1—*Adjustable and Plain Yoke and Eye, Figs. 1 and 2*

SERIES	A	THREADS PER INCH, B	C	D	E	F	G	H Fork ±0.010 Eye +0.000 −0.010	I ±0.010	J	K	L Nom	L Tolerance plus 0.001; minus
Light	No. 10	32	1 9/16	1 1/4	1 1/4	1	7/16	3/16	7/16	5/16	3/8	3/16	0.001
	1/4	28	2	1 3/4	1 1/4	1 1/4	5/8	9/32	5/8	7/16	1/2	1/4	0.001
	5/16	24	2 1/4	2	1 3/8	1 7/16	3/4	11/32	3/4	1/2	19/32	5/16	0.001
	3/8	24	2 1/2	2 1/8	1 1/2	1 5/8	27/32	7/16	7/8	5/8	11/16	3/8	0.001
	7/16	20	2 7/8	2 1/4	1 1/2	1 7/8	1	1/2	1	23/32	13/16	7/16	0.001
	1/2	20	3	2 1/2	1 3/4	1 7/8	1 1/8	9/16	1 1/8	13/16	15/16	1/2	0.002
Heavy	1/2	20	4 3/16	2 1/2	1 3/4	3 1/16	1 1/8	9/16	1 1/8	13/16	15/16	1/2	0.002
	5/8	18	4 15/16	2 7/8	2	3 11/16	1 7/16	11/16	1 3/8	1 1/16	1 3/16	5/8	0.002
	3/4	16	6 1/16	3 5/8	2 3/8	4 9/16	1 11/16	13/16	1 5/8	1 1/4	1 7/16	3/4	0.002
	7/8	14	7 1/8	4	2 3/4	5 1/4	2	15/16	1 7/8	1 7/16	1 11/16	7/8	0.002
	1	14	8	4 1/2	3	6	2 1/2	1 1/16	2 1/8	1 5/8	1 15/16	1	0.002

TABLE 2—*Rod-End Pin and Cotter Pin, Fig. 3*

PIN DIAMETER A Nom	PIN DIAMETER A Max	PIN DIAMETER A Min	B	C	D, MIN	E	F	G	H	DRILL NO.
3/16	0.186	0.181	5/16	1/16	31/64	19/32	21/32	3/64	1/64	0.0781 (5/64)
1/4	0.248	0.243	3/8	3/32	43/64	51/64	57/64	1/16	1/32	
5/16	0.311	0.306	7/16	3/32	13/16	31/32	1 1/16	5/64	1/32	
3/8	0.373	0.368	1/2	1/8	15/16	1 3/32	1 7/32	5/64	1/32	0.1094 (7/64)
7/16	0.436	0.431	9/16	5/32	1 1/16	1 15/64	1 25/64	3/32	3/64	
1/2	0.496	0.491	5/8	5/32	1 13/64	1 27/64	1 37/64	7/64	3/64	0.1406 (9/64)
5/8	0.621	0.616	13/16	13/64	1 15/32	1 23/32	1 59/64	9/64	1/16	
3/4	0.746	0.741	15/16	1/4	1 3/4	2 3/64	2 19/64	5/32	5/64	
7/8	0.871	0.866	1 1/16	5/16	2 1/64	2 11/32	2 21/32	3/16	3/32	0.1719 (11/64)
1	0.996	0.991	1 3/16	11/32	2 17/64	2 5/8	2 31/32	7/32	7/64	

Involute Splines

SAE Standard

Report of Parts and Fittings Division approved January 1945 and last revised by Parts and Fittings Technical Committee January 1950. This SAE Standard conforms with the American Standard for Involute Splines, Side Bearing, ASA B5.15-1950.

[The original involute standard (1946 SAE Handbook) was developed jointly by the members of the SAE Parts and Fittings Division and Technical Committee 13 of ASA Sectional Committee B5—Small Tools and Machine Tool Elements, sponsored by SAE, ASME, NMTBA, and AGMA. Subsequently, the sponsor group was enlarged to include membership from the airframes industry (NASC) and revisions were recommended to provide for interchangeability with the SAE Aeronautical Spline Standard, AS 84.

With the American Standard for Gear Tolerances and Inspection, ASA B6.6-1946 as the basis, effective fits were arrived at as being 60% of the total of all errors that were considered as a working maximum and Table 2 (Section 20) was revised to include both dimensions and effective fits determined on a spline having 25 teeth. The illustrations were revised to include the fillet-root type, the nomenclature was extended, and the dimensions for both flat- and fillet-root types were included in the tables. Minor-diameter fits are given in separate tables for diametral pitches from 5/10 through 16/32. All data in the standard were checked and rearranged for most convenient reference and use. Information and instructions for using the Standard, supplemented by data on the formulas from which the Standard was developed, on pin measurements, shapers, cutters, hobs and broaches, and engineering suggestions on using the Standard are also given.]

Key to Abbreviations

App—Approximate	*Ht—Height*
Cl—Class	*Maj—Major*
Circ—Circular	*Min—Minor, Minimum*
Col—Column	*Max—Maximum*
Diam—Diameter	*Rad—Radius*
Inv—Involute	*Ref—Reference*

1. **Definition and Scope**—Involute splines are multiple keys in the general form of internal and external involute gear teeth, as used to prevent relative rotation of cylindrically fitted machine parts. Involute splines can be machined by the same methods and equipment as those customarily used in the production of gears. Diametral pitch, as in gears, means the number of teeth per inch of pitch diameter. The spline teeth are one-half the depth of standard gear teeth, and in the fractional designation used, the numerator controls the pitch diameter, and the denominator (always twice the numerator) controls the tooth depth. For simplification in calculation, the numerator (such as 8 in 8/16) is always used as P in this standard.

The range covered is from 1/2 (one/two) diametral pitch to 48/96 diametral pitch and from 6 teeth to 50 teeth for both flat-root and fillet-root types.

2. **Nomenclature**—The nomenclature (Fig. 1) agrees as nearly as possible with the standard gear nomenclature adopted by the American Standards Association, except that the words *root diameter*, *outside diameter*, and *inside diameter* have been changed to *major diameter* and *minor diameter* to avoid confusion. Where new letters have been used for symbols, there was no parallel in AGMA 111.01 (March 1944) or ASA B6.5-1943.

3. **Pressure Angle**—The pressure angle is 30 deg.

4. **Basic Tooth Form**—These splines are based on diametral pitch and involute form of the proportions given in Section 6. (Fig. 2 shows the actual size of external splines.)

5. **Basic Tooth Proportions**—Basic dimensions for both internal and external splines are pitch diameter, circular pitch, circular tooth thickness, circular space width, addendum, dedendum, major diameter, and minor diameter. Because of the almost universal practice of broaching the internal spline, the internal spline has been held to basic dimensions and the external-spline dimensions varied to control the fit. This corresponds to the general practice of fitting to a drilled or reamed hole because of the fixed condition of the finishing tools and gages.

6. **Basic Formulas**—Basic formulas for dimensions for both flat- and fillet-root type splines are given in Tables 1a and 1b.

TABLE 1a—*Basic Formulas*,[a] *Flat and Fillet Root*

Pitch diameter[b]	$D = \frac{N}{P}$
Circular pitch	$p = \frac{3.141593}{P}$
Circular tooth thickness	$t = \frac{1.570796}{P}$
Addendum	$a = \frac{0.500}{P}$
Dedendum[c]	$b = \frac{0.600}{P} + 0.002$
Major diameter, external	$D_o = \frac{N+1}{P}$
TIF diameter, internal	$TIF = \frac{N+1}{P}$
Minor diameter, minor-diameter fits only	$D_R = \frac{N-1}{P}$
TIF diameter, external	$TIF = \frac{N-1}{P}$

[a] See Table 26 for other formulas.
[b] Diametral pitch P is that which determines the diameter, as 8 in 8/16. See Fig. 1.
[c] For major-diameter fits, the dedendum of the internal spline is the same as the addendum; and for minor-diameter fits, the dedendum of the external spline is the same as the addendum.

(*Continued on next page.*)

TABLE 1b—*Basic Formulas*,[a] *Fillet Root Only*

Diametral Pitch[b]	1/2 thru 12/24	16/32 thru 48/96
Major diameter, internal	$D_o = \frac{N + 1.8}{P}$	$D_o = \frac{N + 1.8}{P}$
Minor diameter, external	$D_R = \frac{N - 1.8}{P}$	$D_R = \frac{N - 2}{P}$
Dedendum, internal	$b_1 = \frac{0.900}{P}$	$b_1 = \frac{0.900}{P}$
Dedendum, external	$b_1 = \frac{0.900}{P}$	$b_1 = \frac{1.000}{P}$

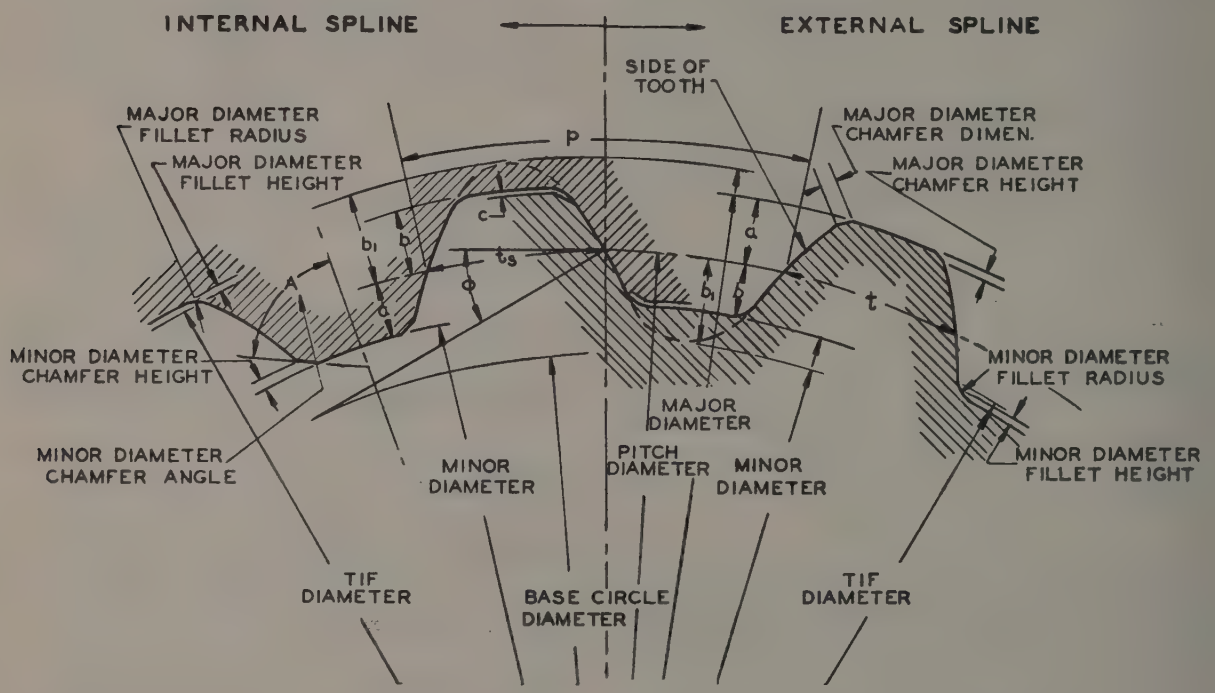
[a] See Table 26 for other formulas.
[b] Diametral pitch P is that which determines the diameter, as 8 in 8/16. See Fig. 1.

7. **Tables**—Tables 5a and 5b are for one/two diametral pitch and are masters for all other tables. Dimensions for any diametral pitch may be obtained by dividing the appropriate table dimensions by the desired diametral pitch. (See footnote b, Table 1.)

Dimensions for circular tooth thickness, addendum, and dedendum in headings for Tables 5 to 25 are basic. Other table dimensions are inversely proportional to those on Tables 5a and 5b for Col 2, 3, 4, 7, 8, 9B, 10, 19, 20, 22, 23, 24, 35, and 39. Tolerances are determined by manufacturing experience and not by proportions. Table 26 shows formulas for all dimensions and also the tolerances used.

Table dimensions have been rounded off by using the last figure retained unchanged if that which follows is less than 5, and increasing the last figure retained to the next larger when the following figure is 5 or more. All dimensions are in inches.

8. **True Involute Form Modifications**—For major-diameter fits, the *TIF* of the internal spine must be reduced from the basic (Section 6) by twice the height of the major-diameter fillet, Col 8. Likewise, for minor-diameter fits, the *TIF* of the



P = diametral pitch
p = circular pitch
a = addendum
b = dedendum, flat root
b_1 = dedendum, fillet root
c = clearance
t = circular tooth thickness
t_s = circular space width
ϕ = pressure angle
ϕ_e = pressure angle at pin center, external
ϕ_i = pressure angle at pin center, internal

M_e = measurement over pins, external
M_i = measurement between pins, internal
N = number of teeth
D = pitch diameter
D_b = base-circle diameter
D_o = major diameter
D_R = minor diameter
TIF = diameter at junction of involute form with fillet
d_e = measuring-pin diameter, external
d_i = measuring-pin diameter, internal

FIG. 1—TOOTH NOMENCLATURE

external spline must be increased by twice the height of the minor-diameter fillet, Col 23.

9. **External-Spline Fillets and Chamfers**—The fillet at the minor diameter is formed by the generating action of the hob or shaper cutter. Since the shaping operation involves two circular parts, the tool and the work, the approximate radius formed is greater than in hobbing, and the height needed for shaping is shown in Col 23. Col 22 is derived from the same data. The major-diameter chamfer is obtained by the generating action of the cutter or hob, or it can be made by special machining or hand operation. The dimension given in Col 19 (length of the approximate flat of the chamfer) and height in Col 20 are affected by the tool with depth of cut as controlled by Col 28, 29, and 30. Fillet radius, Col 22, is based on a 20-tooth cutter design.

10. **Internal-Spline Fillets and Chamfers**—The fillet at the major diameter may be constant for broached parts; but if cut with a shaper cutter, the generating action forms a fillet, the radial height of which is shown in Col 8. The minor-diameter chamfer may be cut as a flat by a broach but will be slightly curved if produced by a shaper cutter. Col 35 provides sufficient height for shaper operation, which is greater than needed for any other method. Angle, Col 34, shows in degrees the angle between the tooth center and the flat of the chamfer produced by the special chamfer cutter shown with Table 30. Fillet radius, Col 7, is based on a 4-tooth cutter design.

11. **Measurement of Tooth Thickness**—Tooth thickness is determined by measuring over pins for the external spline and between pins for the internal spline. The diameter of the measuring pin is optional within a narrow range. It is not necessary that a pin contact exactly at the pitch circle. For the sake of uniformity and to follow a satisfactory practice, this Standard incorporates a recommended diameter indicated at the top of each table. Measurements with pins will not check spacing errors which must be determined by other means. (See Section 29.) Pins for measuring flat-root internal splines may be flattened as shown in Fig. 3B; but for external splines, those specified will clear the minor diameter. For further information on pin measurements, see Section 25.

With Figs. 3A and 3B are formulas (1), (2), and (3) which are used to calculate dimensions over pins, and formulas (4), (5), and (6) which are used to calculate measurements between pins.

12. **Tooth Dimensions**—Because of allowable errors (see Section 29) which must be provided for in determining fits, space width must be increased and tooth thickness decreased in relation to the diameter of the part and, therefore, in relation to the number of teeth. The minimum space width and the maximum tooth thickness are constant for each type of fit, but the maximum space width must be selected from Col 15, and the minimum tooth thickness from Col 31, 32, or 33 for the number of teeth used. Table 26 shows the formulas used to determine these dimensions.

13. **Drawings**—It is important that uniform methods be used to show complete information on detail drawings. Figs. 4A, 4B, 5A, and 5B show the sections recommended, the placing of di-

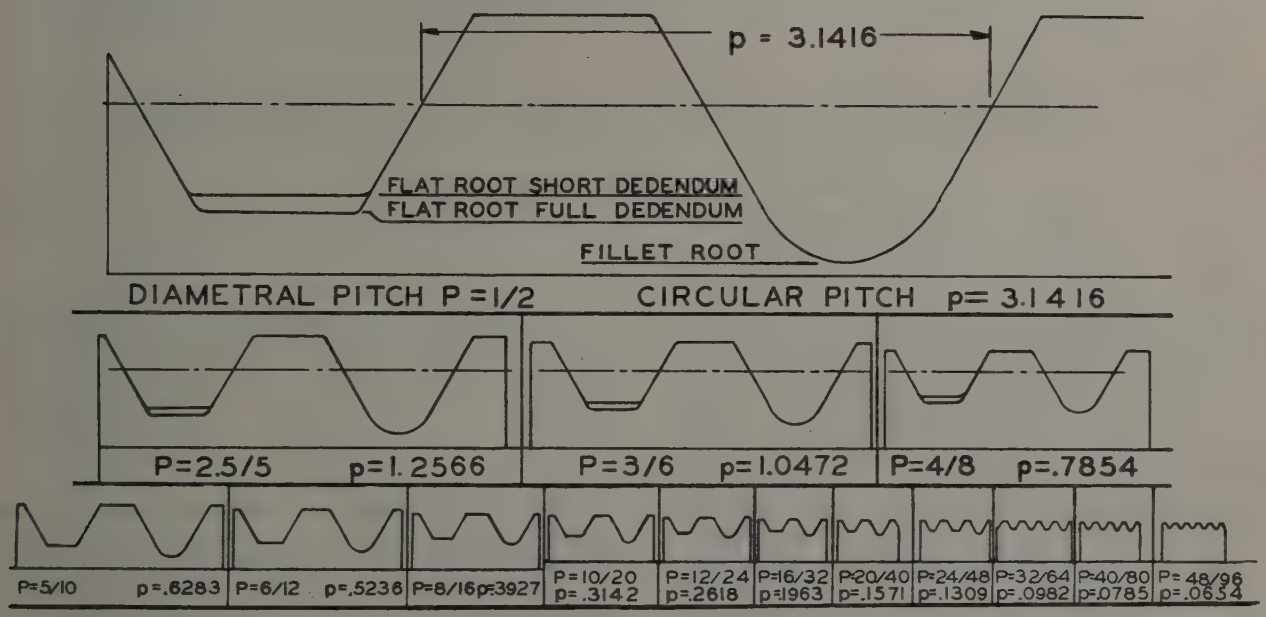
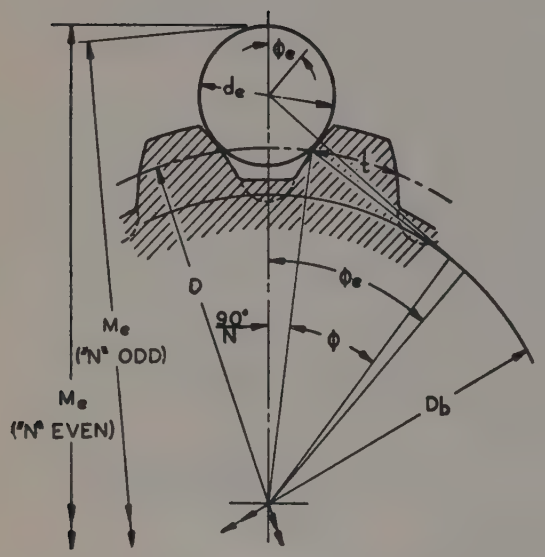


Fig. 2—Actual Size of External Splines



ϕ = pressure angle at pitch diameter, 30 deg
ϕ_e = pressure angle at pin center

$$\text{Inv } \phi_e = \text{Inv } 30° + \frac{d_e}{D_b} + \frac{t}{D^*} - \frac{\pi}{N} \tag{1}$$

From Inv ϕ_e find ϕ_e in degrees

When N is even,

$$M_e = D_b^* \sec \phi_e + d_e,$$

or

$$M_e = \frac{D_b^*}{\cos \phi_e} + d_e \tag{2}$$

When N is odd,

$$M_e = D_b^* \sec \phi_e \cos\left(\frac{90°}{N}\right) + d_e,$$

or

$$M_e = \frac{D_b^* \cos\left(\frac{90°}{N}\right)}{\cos \phi_e} + d_e \tag{3}$$

Example:

Standard dimensions for $N = 20$, $P = 10/20$, Class B fit, $d_e = 0.1920$

Basic t (tooth thickness) $= 0.1571$

Allowable errors $\times$ 60% + machining tolerance (Table 26)
$= 0.0001\ (0.054N + 19) = 0.0020$

Minimum tooth thickness for measurement $t = 0.1551$

$$\text{Inv } \phi_e = 0.053751 + 0.110851 + \frac{0.1551}{2.0000} - 0.157080 = 0.085072$$

$\phi_e = 34.491456$ deg

$M_e = 1.732051 \sec 34.491456° + 0.1920 = 2.2935$

* For all calculations, the base-circle diameter and the pitch diameter should be accurate to the sixth decimal place. To obtain this accuracy, divide the dimension for D_b in Table 4 by the diametral pitch P (see Section 6). To obtain D to the sixth decimal place, divide the pitch diameter from Table 5 by the diametral pitch P.

FIG. 3A—FORMULAS FOR PIN MEASUREMENTS, EXTERNAL SPLINE

mensions, and involute-spline data required. Much trouble may be avoided by following these specimen drawings exactly. Boxed notes are for instruction and not to be placed on drawing.

14. **Key to Tables with Column Numbers**—Because of the different types of splines included in this Standard, it is desirable to use a key so that the proper dimensions will be selected. This key is incorporated in Table 3.

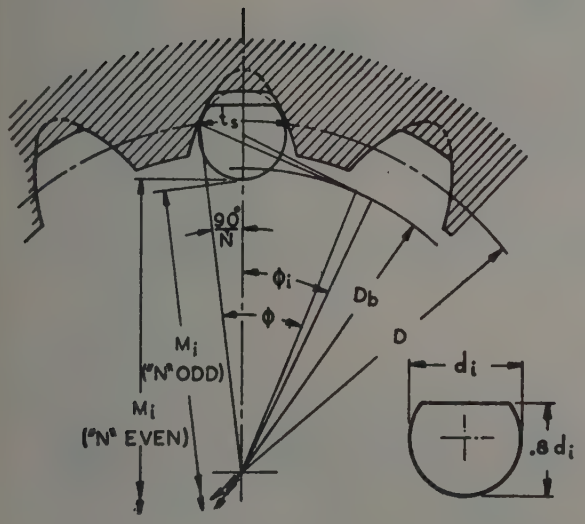
15. **Cutting Tools**—In Appendix 1, Tables 30a and 30b show, for internal splines, the minimum difference of teeth between internal spline and cutter and a suggested cutter design for general use. Table 30c shows a design for general use with external splines, and Table 30d shows preferred cutters which may be used for either. For the fillet-root type, the addendum of the shaper cutter, hob, or broach may be checked by layout or other means to assure the required involute clearance. The addendum is also influenced by the lack of tangency between the tooth profile and the tip radius of the tool. The part drawing should show a tolerance for the dedendum (applied to major or minor diameter) because of the tool tolerances and allowances for wear as well as the depth of cut to obtain the desired fit. (See also Section 19.) Fig. 8 shows the dimensions of a 1/2-diametral-pitch hob tooth for flat- and fillet-root types. Table 31 lists the recommended overall dimensions for finishing hobs. Fig. 9 shows a 1/2-diametral-pitch broach tooth.

16. **Ball-Bearing Installations**—Because of the wide use of ball bearings on splined shafts, it will often be convenient to know the nearest size of spline for any given ball-bearing bore. Table 33 provides for such a selection.

17. **Types of Fits**—There are three methods of fitting splined members together:

Major Diameter—On the major diameter, the fit is controlled by varying the major diameter of the external spline.

Sides of Teeth—On the sides of the teeth, the fit is con-



ϕ = pressure angle at pitch diameter, 30 deg
ϕ_i = pressure angle at pin center

$$\text{Inv}\,\phi_i = \text{Inv}\,30° + \frac{t_s}{D} - \frac{d_i}{D_b} \tag{4}$$

From Inv ϕ_i find ϕ_i in degrees

When N is even,

$$M_i = D_b^* \sec \phi_i - d_i,$$

or

$$M_i = \frac{D_b^*}{\cos \phi_i} - d_i \tag{5}$$

When N is odd,

$$M_i = D_b^* \sec \phi_i \cos\left(\frac{90°}{N}\right) - d_i,$$

or

$$M_i = \frac{D_b^* \cos\left(\frac{90°}{N}\right)}{\cos \phi_i} - d_i \tag{6}$$

Example:

Standard dimensions for $N = 20$, $P = 10/20$, internal spline
$d_i = 0.1440$
Basic t_s (space width) $= 0.1571$
Allowable errors $\times$ 60% + machining tolerance (Table 26)
$= 0.001\ (0.072N + 24) = 0.0025$

Maximum space width for measurement $t_s = 0.1596$
Inv $\phi_i = 0.053751 + 0.079800 - 0.083138 = 0.050413$
$\phi_i = 29.412396$ deg
$M_i = 1.732051 \sec 29.412396° - 0.1440 = 1.8443$

* For all calculations, the base-circle diameter and the pitch diameter should be accurate to the sixth decimal place. To obtain this accuracy, divide the dimension for D_b in Table 4 by the diametral pitch P (see Section 6). To obtain D to the sixth decimal place, divide the pitch diameter from Table 5 by the diametral pitch P.

FIG. 3B—FORMULAS FOR PIN MEASUREMENTS, INTERNAL SPLINE

trolled by varying the tooth thickness. It is customary to use this type fit for the fillet-root type spline.

Minor Diameter—On the minor diameter, the fit is controlled by varying the minor diameter of the internal spline.

The three types of fits listed above are each divided into three classes:

Sliding Fits—These must have clearance at all points.

Close Fits—These must be close on either the major diameter, sides of teeth, or minor diameter.

Press Fits—These must have an interference on either the major diameter, sides of teeth, or minor diameter.

For all types and classes of fits, the internal pin measurements are the same and are to be found in Col 14 of Tables 5 to 19. Table 3 shows the correct combinations of dimensions for any desired fit.

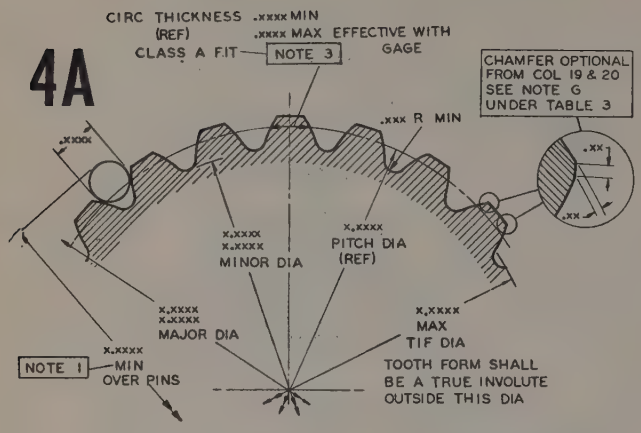
18. **Special Fits**—The fits provided for in Tables 5 to 19 cover usual practice and will be acceptable in a majority of installations. If it is necessary to use a special fit of the side-bearing type, the basic data in Table 4 together with the formulas in Fig. 3A may be used for its calculation. For further suggestions relative to special fits, see Sections 21 and 24 and Table 27.

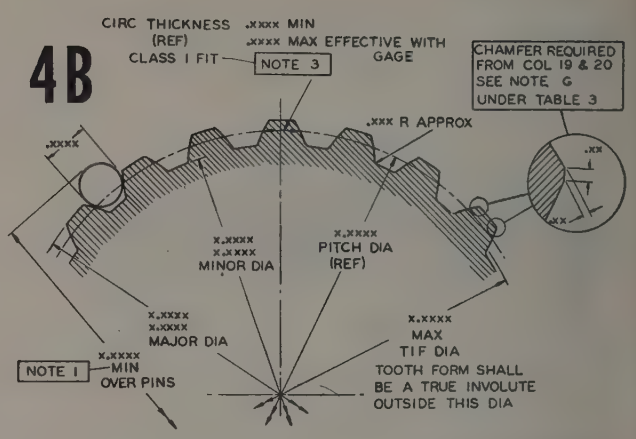
19. **Tolerances**—In the cutting of a splined part, a machine-tool adjustment may vary the depth of cut. The tolerances suggested are listed in Table 26. (See also Section 15.)

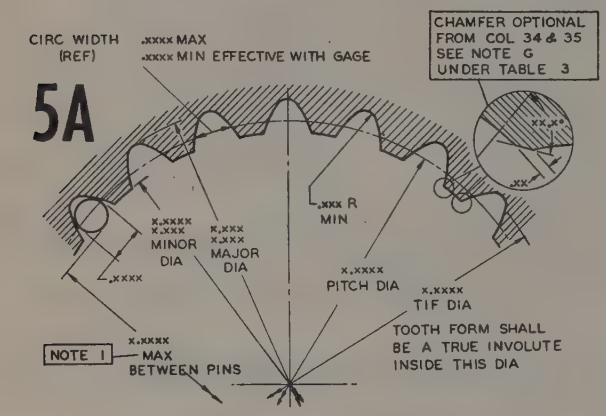
When allowable (unavoidable) errors (Section 29) are added to machining tolerances it is possible, when using Col 9B, that a side-bearing fit might become a major-diameter fit, and vice-versa, under extreme conditions. Slight modification of the major diameter will correct such a condition.

20. **Effective Fits**—The effective clearance (positive or negative) between two splined parts is equal to the effective space width of the internal minus the effective tooth thickness of the external spline. (See Sections 21 and 25.) Dimensional and effective clearances are given in Table 2.

21. **Use of the Tables**—*Example:* Class A fit, 10/20 diametral







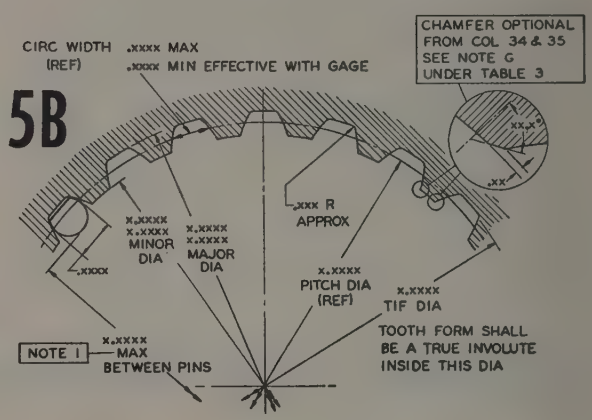


FIG. 4A—FILLET-ROOT DIMENSIONING DRAWING, EXTERNAL SPLINE (SEE TABLE 3)

FIG. 5A—FILLET-ROOT DIMENSIONING DRAWING, INTERNAL SPLINE (SEE TABLE 3)

FIG. 4B—FLAT-ROOT DIMENSIONING DRAWING, EXTERNAL SPLINE (SEE TABLE 3)

FIG. 5B—FLAT-ROOT DIMENSIONING DRAWING, INTERNAL SPLINE (SEE TABLE 3)

Notes for Figs. 4A, 4B, 5A, and 5B: (Boxed notes are for instruction only)

Note 1—See Section 25. For machining tolerances, see Table 26.

Note 2—The data below should be given for both internal and external splines. For allowable errors, see Table 27.

Number of teeth	xx	Maximum out of roundness	.xxxx
Diametral pitch	xx/xx	Maximum cumulative pitch error (any two teeth)	.xxxx
Pressure angle	xx°	Maximum involute profile error	.xxxx
Base-circle diameter	x.xxxx	Maximum lead error	.xxxx

Note 3—Desired fit should be given on the drawing of the external-splined part.

TABLE 2—*Dimensional and Effective Clearances*[a]

DIAMETRAL PITCH	CLASS A				CLASS B				CLASS C			
	Dimensional clearance[b,c]		Effective clearance[d]		Dimensional clearance[b,c]		Effective clearance[d]		Dimensional clearance[b, c]		Effective clearance[d]	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1/2	+0.0076	+0.0116	+0.0005	+0.0045	+0.0056	+0.0091	−0.0015	+0.0020	+0.0026	+0.0061	−0.0045	−0.0010
2.5/5	+0.0057	+0.0097	+0.0005	+0.0045	+0.0037	+0.0072	−0.0015	+0.0020	+0.0010	+0.0045	−0.0042	−0.0007
3/6	+0.0052	+0.0092	+0.0005	+0.0045	+0.0032	+0.0067	−0.0015	+0.0020	+0.0005	+0.0040	−0.0042	−0.0007
4/8 and 5/10	+0.0044	+0.0084	+0.0005	+0.0045	+0.0024	+0.0059	−0.0015	+0.0020	+0.0003	+0.0038	−0.0036	−0.0001
6/12 and 8/16	+0.0039	+0.0069	+0.0005	+0.0035	+0.0021	+0.0051	−0.0013	+0.0017	+0.0004	+0.0034	−0.0030	−0.0000
10/20 thru 20/40	+0.0037	+0.0062	+0.0005	+0.0030	+0.0021	+0.0046	−0.0011	+0.0014	+0.0002	+0.0027	−0.0030	−0.0005
24/48 thru 48/96	+0.0037	+0.0057	+0.0005	+0.0025	+0.0023	+0.0043	−0.0009	+0.0011	+0.0002	+0.0022	−0.0030	−0.0010

[a] Based on using machining tolerances plus 60% of all allowable errors cumulatively, not including lead.
[b] For 25 teeth.
[c] The maximum dimensional clearance is obtained by subtracting dimension in Col 31, 32, or 33 from that in Col 15. The minimum dimensional clearance is obtained by subtracting the sum of the machining tolerances for Col 15 and that for either Col 31, 32, or 33, as listed in Table 26, from the maximum dimensional clearance.
[d] The minimum effective clearance is obtained by subtracting the dimension (maximum effective) in the heading over Col 31, 32, or 33 from the dimension (minimum effective) in the heading over Col 15. The maximum effective clearance is obtained by adding to the minimum effective clearance the machining tolerances for Col 15 and that for either Col 31, 32, or 33 as listed in Table 26.

pitch, 25 teeth, flat root. Use Table 3 as a key, and all other dimensions will be found on Tables 12a, 12b, and 27. For external spline, flat root, make drawing in accordance with Fig. 4B. For internal spline, flat root, make drawing in accordance with Fig. 5B.

22. **Helical Splines**—Helical splines, like helical gears, must be specially designed, and these data are not included in this Standard.

23. **Odd Pitches**—For special applications or to maintain interchangeability with old parts, it is sometimes necessary to use pitch combinations such as 20/30 or 7/16. In such cases, the pitch diameter is always determined by the numerator of the fractional designation, and the addendum and dedendum by the denominator. For example, a 25 tooth 20/30 spline would have a pitch diameter of 25 ÷ 20 = 1.2500 and an addendum of 1 ÷ 30 = 0.0333, and the space width may be taken from Table 15 (20/40). If a 7/16 is selected, the pitch diameter should be calculated from the "7", and the addendum may be taken from the 8/16 data in Table 11. Other combinations may also be used, such as 5/20, by selecting pitch-diameter figures from the 5/10 table and the addendum and dedendum figures from the 10/20 table.

24. **Special Fits**—If table dimensions do not give the desired fit, slight variations may be made as follows: Multiply the difference between the basic tooth thickness (Col 15 heading) and the desired tooth thickness by the factor E from Table 4 and

How to Use Tables—See Also Section 21

EXTERNAL SPLINE	NO LEAD ERROR		WITH LEAD ERROR ALLOWANCE		
Pitch diameter	Col 2	2.5000	Col 2	2.5000	Assume length of 3.75″
Base-circle diameter	Col 3	2.1651	Col 3	2.1651	Lead error, Table 27, 0.0004
Major diameter	Col 24	2.6000	Col 24	2.6000	
Minor diameter	Col 21	2.3760	Col 21	2.3760	
True involute form diameter	Col 27	2.4000	Col 27	2.4000	
Minor-diameter fillet	Col 22	0.010	Col 22	0.010	
Minor-diameter fillet height	Col 23	0.008	Col 23	0.008	
Measurement over pins	Col 28	2.7870	2.7870 − 0.0002E =	2.7867	For E, see Table 4
Tooth thickness	Col 31	0.1535–0.1566	Ded 0.0002,	0.1533–0.1564	Lead error 0.0004 × 0.60 = 0.0002
INTERNAL SPLINE	NO LEAD ERROR		WITH LEAD ERROR ALLOWANCE		
Pitch diameter	Col 2	2.5000	Col 2	2.5000	Assume length of 3.75″
Base-circle diameter	Col 3	2.1651	Col 3	2.1651	Lead error, Table 27, 0.0004
Major diameter	Col 9A	2.6240	Col 9A	2.6240	
Minor diameter	Col 6	2.4000	Col 6	2.4000	
True involute form diameter	Col 10	2.6000	Col 10	2.6000	
Major-diameter fillet	Col 7	0.021	Col 7	0.021	
Major-diameter fillet height	Col 8	0.010	Col 8	0.010	
Measurement between pins	Col 14	2.3396	2.3396 + 0.0002F =	2.3400	For F, see Table 4
Space width, min and max	Col 15	0.1571–0.1597	Add. 0.0002,	0.1573–0.1599	Lead error 0.0004 × 0.60 = 0.0002

TABLE 3—*Dimensioning Key*[a]

TYPE OF FIT[b]	CLASS OF FIT	INTERNAL AND EXTERNAL		INTERNAL							EXTERNAL								
		Pitch diam	Base-cir diam	Maj diam	Min diam	*TIF* diam	Major-diam fillet		Meas bet pins	Space width[c]	Maj diam	Min diam	*TIF* diam	Minor-diam fillet		Major diam chamfer		Meas over pins	Tooth thick[d]
							Rad	Ht						Rad	Ht	Dim	Ht		
Major diam	Sliding I	2	3	4	6	5	7	8	14	15	16	21	27	22	23	19	20	28	31
	Close II	2	3	4	6	5	7	8	14	15	17	21	27	22	23	19	20	28	31
	Press III	2	3	4	6	5	7	8	14	15	18	21	27	22	23	19	20	28	31
Sides of teeth, flat root	Sliding A	2	3	9[f]	6	10	7	8	14	15	24	21	27	22	23	19[g]	20	28	31
	Close B	2	3	9[f]	6	10	7	8	14	15	24	21	27	22	23	19[g]	20	29	32
	Press C	2	3	9[f]	6	10	7	8	14	15	24	21	27	22	23	19[g]	20	30	33
Sides of teeth, fillet root[e]	Sliding A	2	3	12	11	10	13	—	14	15	24	25	27	26	—	19[g]	20	28	31
	Close B	2	3	12	11	10	13	—	14	15	24	25	27	26	—	19[g]	20	29	32
	Press C	2	3	12	11	10	13	—	14	15	24	25	27	26	—	19[g]	20	30	33

[a] Numbers given refer to column numbers of Tables 5 through 19. An example showing use of the tables is in Section 21. For drawing examples, see Figs. 4A, 4B, 5A, and 5B.
[b] Dimensions for minor-diameter fits are given in Tables 20 through 25.
[c] Use minimum dimension given over column heading and maximum from Col 15.
[d] Use maximum dimension given over column heading and minimum from Col 31, 32, or 33.
[e] A fillet-root type spline will mesh with the flat-root type except when Col 9B is used for the internal spline. See footnote c, Tables 5a through 19a.
[f] Col 9A is to be used where full dedendum is desired, with clearance over external major diameter. Col 9B may be used when full dedendum is not required and broaching of the internal spline is desired.
[g] Chamfering, which is specified above, is required for a major-diameter fit. In some manufacturing, a chamfer is desirable because it removes burrs which are a hazard in assembly processes and also saves injuries to those handling the parts. These chamfers are optional and can cause only slight loss of tooth contact. See Table 30 and Fig. 6.

subtract the product from the basic over-pin measurement, Table 29. All special loose fits should be checked to determine that the major diameter of the external spline and the minor diameter of the internal spline do not interfere with the *TIF* of the mating part. In order to avoid changing hobs or cutters, the minor diameter of the internal spline may be increased and the major diameter of the external spline decreased by the amount of the extra clearance. The major diameter of the internal spline and minor diameter of the external spline must also be adjusted.

(*Text continued after Table 26.*)

TABLE 4—*Basic Data*

N	1/2 DIAMETRAL PITCH			ALL PITCHES						
	Internal and external		External	Internal			Int and ext	External		
	D_b	$D_b \cos \frac{90°}{N}$	Measurement over pins	$\frac{t_s}{D}$	$\frac{d_i}{D_b}$	F	$\cos \frac{90°}{N}$	$\frac{d_s}{D_b}$	$\frac{\pi}{N}$	E
1	2	3	4	5	6	7	8	9	10	11
6	5.196152		8.8660	0.261799	0.277128	1.91		0.369504	0.523599	1.305
7	6.062178	5.910186	9.6819	0.224399	0.237538	1.83	0.974928	0.316718	0.448799	1.302
8	6.928203		10.8944	0.196350	0.207846	1.86		0.277128	0.392699	1.362
9	7.794229	7.675817	11.7535	0.174533	0.184752	1.81	0.984808	0.246336	0.349066	1.364
10	8.660254		12.9144	0.157080	0.166277	1.83		0.221703	0.314159	1.406
11	9.526279	9.429316	13.8003	0.142800	0.151161	1.80	0.989821	0.201548	0.285599	1.409
12	10.392305		14.9295	0.130900	0.138564	1.81		0.184752	0.261799	1.440
13	11.258330	11.176244	15.8335	0.120830	0.127905	1.79	0.992709	0.170540	0.241661	1.443
14	12.124356		16.9412	0.112200	0.118769	1.80		0.158359	0.224399	1.467
15	12.990381	12.919218	17.8584	0.104720	0.110851	1.78	0.994522	0.147802	0.209440	1.471
16	13.856406		18.9507	0.098175	0.103923	1.79		0.138564	0.196350	1.490
17	14.722432	14.659629	19.8778	0.092400	0.097810	1.78	0.995734	0.130413	0.184800	1.493
18	15.588457		20.9584	0.087266	0.092376	1.78		0.123168	0.174533	1.509
19	16.454483	16.398282	21.8934	0.082673	0.087514	1.78	0.996584	0.116686	0.165347	1.512
20	17.320508		22.9649	0.078540	0.083138	1.78		0.110851	0.157080	1.525
21	18.186533	18.135680	23.9062	0.074800	0.079179	1.77	0.997204	0.105573	0.149600	1.528
22	19.052559		24.9704	0.071400	0.075580	1.77		0.100774	0.142800	1.539
23	19.918548	19.872149	25.9168	0.068295	0.072294	1.77	0.997669	0.096392	0.136591	1.541
24	20.784610		26.9752	0.065450	0.069282	1.77		0.092376	0.130900	1.551
25	21.650635	21.607912	27.9259	0.062832	0.066511	1.77	0.998027	0.088681	0.125664	1.553
26	22.516660		28.9793	0.060415	0.063953	1.76		0.085270	0.120830	1.562
27	23.382686	23.343126	29.9337	0.058178	0.061584	1.76	0.998308	0.082112	0.116355	1.564
28	24.248711		30.9829	0.056100	0.059385	1.76		0.079179	0.112200	1.571
29	25.114737	25.077904	31.9405	0.054165	0.057337	1.76	0.998533	0.076449	0.108331	1.573
30	25.980762		32.9862	0.052360	0.055426	1.76		0.073901	0.104720	1.580
31	26.846787	26.812337	33.9465	0.050671	0.053638	1.76	0.998717	0.071517	0.101342	1.581
32	27.712813		34.9890	0.049087	0.051962	1.76		0.069282	0.098175	1.587
33	28.578838	28.546468	35.9517	0.047600	0.050387	1.76	0.998867	0.067183	0.095200	1.589
34	29.444864		36.9916	0.046200	0.048905	1.76		0.065207	0.092400	1.594
35	30.310889	30.280368	37.9565	0.044880	0.047508	1.76	0.998993	0.063344	0.089760	1.596
36	31.176914		38.9939	0.043633	0.046188	1.76		0.061584	0.087266	1.600
37	32.042940	32.014068	39.9607	0.042454	0.044940	1.76	0.999100	0.059920	0.084908	1.602
38	32.908965		40.9960	0.041337	0.043757	1.75		0.058343	0.082673	1.606
39	33.774991	33.747599	41.9645	0.040277	0.042635	1.75	0.999189	0.056847	0.080554	1.608
40	34.641016		42.9980	0.039270	0.041569	1.75		0.055426	0.078540	1.611
41	35.507041	35.480986	43.9680	0.038312	0.040555	1.75	0.999266	0.054074	0.076624	1.613
42	36.373067		44.9996	0.037400	0.039590	1.75		0.052786	0.074800	1.616
43	37.239092	37.214248	45.9711	0.036530	0.038669	1.75	0.999333	0.051559	0.073060	1.617
44	38.105118		47.0013	0.035700	0.037790	1.75		0.050387	0.071400	1.621
45	38.971143	38.947403	47.9740	0.034907	0.036950	1.75	0.999391	0.049267	0.069813	1.622
46	39.837168		49.0028	0.034148	0.036147	1.75		0.048196	0.068295	1.625
47	40.703194	40.680464	49.9766	0.033421	0.035378	1.75	0.999442	0.047171	0.066842	1.626
48	41.569219		51.0041	0.032725	0.034641	1.75		0.046188	0.065450	1.629
49	42.435245	42.413442	51.9790	0.032057	0.033934	1.75	0.999486	0.045245	0.064114	1.630
50	43.301270		53.0055	0.031416	0.033255	1.75		0.044341	0.062832	1.632

Constants, $\pi = 3.141593$ $\cos 30° = 0.866025$ $\text{Inv } 30° = 0.053751$

$$E = \frac{\cos 30°}{\sin \phi_s} = \frac{\text{Rate of change of } M_s}{\text{Rate of change of } t} \left(\text{For } N \text{ odd, } E = \frac{\cos 30°}{\sin \phi_s} \cos \frac{90°}{N} \right)$$

$$F = \frac{\cos 30°}{\sin \phi_i} = \frac{\text{Rate of change of } M_i}{\text{Rate of change of } t_s} \left(\text{For } N \text{ odd, } F = \frac{\cos 30°}{\sin \phi_i} \cos \frac{90°}{N} \right)$$

TABLE 5a—*1/2 Diametral Pitch, Internal*[a]

1/2 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.5000 Dedendum (See Sec 6)	Circular Pitch, 3.1416 Meas-Pin Diam, 1.4400

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits	
					Flat-Root Side Fit										
						Major-diam fillet		Major diam						Space width	
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad	Measurement between pins	Min effective 1.5708
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance ⟶			$+0.0007 + L^d - 0.0000$	Min	$+0.0050 - 0.0000$	App	Max	$+0.1050 - 0.0000$	$+0.0007 + L^d - (0.0007 + L)$	Min	$+0.0050 - 0.0000$	$+0.1050 - 0.0000$	Min[e]	Max	Dimensional Max[f]
6	6.0000	5.1962	7.0000	6.897	5.2062	0.145	0.052	7.2040	7.0000	7.0000	5.2062	7.8000	0.166	4.4022	1.5755
7	7.0000	6.0622	8.0000	7.881	6.0722	0.160	0.060	8.2040	8.0000	8.0000	6.0722	8.8000	0.194	5.2320	1.5756
8	8.0000	6.9282	9.0000	8.870	7.0400	0.170	0.066	9.2040	9.0000	9.0000	7.0400	9.8000	0.208	6.4043	1.5756
9	9.0000	7.7942	10.0000	9.860	8.0000	0.178	0.071	10.2040	10.0000	10.0000	8.0000	10.8000	0.220	7.2707	1.5757
10	10.0000	8.6603	11.0000	10.852	9.0000	0.184	0.075	11.2040	11.0000	11.0000	9.0000	11.8000	0.230	8.4055	1.5757
11	11.0000	9.5263	12.0000	11.845	10.0000	0.189	0.079	12.2040	12.0000	12.0000	10.0000	12.8000	0.238	9.2955	1.5757
12	12.0000	10.3923	13.0000	12.839	11.0000	0.193	0.081	13.2040	13.0000	13.0000	11.0000	13.8000	0.245	10.4063	1.5758
13	13.0000	11.2583	14.0000	13.834	12.0000	0.196	0.084	14.2040	14.0000	14.0000	12.0000	14.8000	0.249	11.3129	1.5758
14	14.0000	12.1244	15.0000	14.830	13.0000	0.199	0.086	15.2040	15.0000	15.0000	13.0000	15.8000	0.253	12.4070	1.5759
15	15.0000	12.9904	16.0000	15.826	14.0000	0.201	0.088	16.2040	16.0000	16.0000	14.0000	16.8000	0.257	13.3258	1.5759
16	16.0000	13.8564	17.0000	16.823	15.0000	0.203	0.090	17.2040	17.0000	17.0000	15.0000	17.8000	0.260	14.4073	1.5759
17	17.0000	14.7224	18.0000	17.820	16.0000	0.205	0.091	18.2040	18.0000	18.0000	16.0000	18.8000	0.262	15.3357	1.5760
18	18.0000	15.5885	19.0000	18.818	17.0000	0.207	0.093	19.2040	19.0000	19.0000	17.0000	19.8000	0.265	16.4078	1.5760
19	19.0000	16.4545	20.0000	19.815	18.0000	0.208	0.094	20.2040	20.0000	20.0000	18.0000	20.8000	0.267	17.3437	1.5761
20	20.0000	17.3205	21.0000	20.813	19.0000	0.209	0.095	21.2040	21.0000	21.0000	19.0000	21.8000	0.269	18.4081	1.5761
21	21.0000	18.1865	22.0000	21.811	20.0000	0.210	0.096	22.2040	22.0000	22.0000	20.0000	22.8000	0.270	19.3499	1.5761
22	22.0000	19.0526	23.0000	22.810	21.0000	0.212	0.097	23.2040	23.0000	23.0000	21.0000	23.8000	0.272	20.4085	1.5762
23	23.0000	19.9186	24.0000	23.808	22.0000	0.212	0.097	24.2040	24.0000	24.0000	22.0000	24.8000	0.273	21.3552	1.5762
24	24.0000	20.7846	25.0000	24.807	23.0000	0.213	0.098	25.2040	25.0000	25.0000	23.0000	25.8000	0.274	22.4088	1.5763
25	25.0000	21.6506	26.0000	25.805	24.0000	0.214	0.099	26.2040	26.0000	26.0000	24.0000	26.8000	0.275	23.3598	1.5763
26	26.0000	22.5167	27.0000	26.804	25.0000	0.215	0.100	27.2040	27.0000	27.0000	25.0000	27.8000	0.276	24.4089	1.5763
27	27.0000	23.3827	28.0000	27.803	26.0000	0.215	0.100	28.2040	28.0000	28.0000	26.0000	28.8000	0.277	25.3637	1.5764
28	28.0000	24.2487	29.0000	28.802	27.0000	0.216	0.101	29.2040	29.0000	29.0000	27.0000	29.8000	0.278	26.4092	1.5764
29	29.0000	25.1147	30.0000	29.801	28.0000	0.217	0.101	30.2040	30.0000	30.0000	28.0000	30.8000	0.279	27.3669	1.5764
30	30.0000	25.9808	31.0000	30.801	29.0000	0.217	0.102	31.2040	31.0000	31.0000	29.0000	31.8000	0.280	28.4094	1.5765
31	31.0000	26.8468	32.0000	31.800	30.0000	0.218	0.102	32.2040	32.0000	32.0000	30.0000	32.8000	0.281	29.3699	1.5765
32	32.0000	27.7128	33.0000	32.799	31.0000	0.218	0.103	33.2040	33.0000	33.0000	31.0000	33.8000	0.282	30.4097	1.5766
33	33.0000	28.5788	34.0000	33.798	32.0000	0.219	0.103	34.2040	34.0000	34.0000	32.0000	34.8000	0.282	31.3725	1.5766
34	34.0000	29.4449	35.0000	34.798	33.0000	0.219	0.103	35.2040	35.0000	35.0000	33.0000	35.8000	0.283	32.4097	1.5766
35	35.0000	30.3109	36.0000	35.797	34.0000	0.219	0.104	36.2040	36.0000	36.0000	34.0000	36.8000	0.284	33.3748	1.5767
36	36.0000	31.1769	37.0000	36.796	35.0000	0.220	0.104	37.2040	37.0000	37.0000	35.0000	37.8000	0.284	34.4100	1.5767
37	37.0000	32.0429	38.0000	37.796	36.0000	0.220	0.104	38.2040	38.0000	38.0000	36.0000	38.8000	0.285	35.3770	1.5768
38	38.0000	32.9090	39.0000	38.795	37.0000	0.220	0.105	39.2040	39.0000	39.0000	37.0000	39.8000	0.286	36.4101	1.5768
39	39.0000	33.7750	40.0000	39.795	38.0000	0.221	0.105	40.2040	40.0000	40.0000	38.0000	40.8000	0.286	37.3787	1.5768
40	40.0000	34.6410	41.0000	40.794	39.0000	0.221	0.105	41.2040	41.0000	41.0000	39.0000	41.8000	0.286	38.4104	1.5769
41	41.0000	35.5070	42.0000	41.794	40.0000	0.221	0.106	42.2040	42.0000	42.0000	40.0000	42.8000	0.287	39.3805	1.5769
42	42.0000	36.3731	43.0000	42.794	41.0000	0.222	0.106	43.2040	43.0000	43.0000	41.0000	43.8000	0.287	40.4106	1.5770
43	43.0000	37.2391	44.0000	43.793	42.0000	0.222	0.106	44.2040	44.0000	44.0000	42.0000	44.8000	0.287	41.3821	1.5770
44	44.0000	38.1051	45.0000	44.793	43.0000	0.222	0.106	45.2040	45.0000	45.0000	43.0000	45.8000	0.288	42.4107	1.5770
45	45.0000	38.9711	46.0000	45.793	44.0000	0.222	0.106	46.2040	46.0000	46.0000	44.0000	46.8000	0.288	43.3835	1.5771
46	46.0000	39.8372	47.0000	46.792	45.0000	0.222	0.107	47.2040	47.0000	47.0000	45.0000	47.7000	0.288	44.4108	1.5771
47	47.0000	40.7032	48.0000	47.792	46.0000	0.223	0.107	48.2040	48.0000	48.0000	46.0000	48.8000	0.288	45.3849	1.5772
48	48.0000	41.5692	49.0000	48.792	47.0000	0.223	0.107	49.2040	49.0000	49.0000	47.0000	49.8000	0.288	46.4111	1.5772
49	49.0000	42.4352	50.0000	49.791	48.0000	0.223	0.107	50.2040	50.0000	50.0000	48.0000	50.8000	0.289	47.3860	1.5772
50	50.0000	43.3013	51.0000	50.791	49.0000	0.223	0.107	51.2040	51.0000	51.0000	49.0000	51.8000	0.289	48.4113	1.5773

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27). Values in this column were changed October 1949.

TABLE 5b—*1/2 Diametral Pitch, External*[a]

1/2 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.5000 Dedendum (See Sec 6)	Circular Pitch, 3.1416 Meas-Pin Diam, 1.9200

EXTERNAL

N	Major-diameter fit[b]								Fillet root[c]			Dimensions for all fits					
	Major diameter			Major-diam chamfer		Flat-root side fit									Tooth thickness		
						Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	1.5703	1.5723	1.5753
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J[e])	+0.0000 −(0.0006 + J[e])	+0.0009 + J[e] −0.0000	App	Min	+0.0000 −0.1050	App	Max	+0.0000 −0.0100	+0.0000 −0.1050	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	6.9985	6.9999	7.0015	0.228	0.091	4.7960	0.170	0.168	7.0000	4.2000	—	5.2062	8.8590	8.8622	8.8661	1.5654	1.5679	1.5709
7	7.9985	7.9999	8.0016	0.230	0.094	5.7960	0.150	0.150	8.0000	5.2000	—	6.0722	9.6747	9.6780	9.6819	1.5653	1.5678	1.5708
8	8.9985	8.9999	9.0017	0.230	0.095	6.7960	0.140	0.137	9.0000	6.2000	0.379	7.0400	10.8869	10.8903	10.8914	1.5653	1.5678	1.5708
9	9.9985	9.9999	10.0018	0.232	0.097	7.7960	0.130	0.127	10.0000	7.2000	0.373	8.0000	11.7460	11.7494	11.7535	1.5653	1.5678	1.5708
10	10.9985	10.9999	11.0019	0.233	0.098	8.7960	0.120	0.119	11.0000	8.2000	0.367	9.0000	12.9065	12.9100	12.9143	1.5652	1.5677	1.5707
11	11.9985	11.9999	12.0020	0.234	0.099	9.7960	0.116	0.113	12.0000	9.2000	0.362	10.0000	13.7924	13.7959	13.8002	1.5652	1.5677	1.5707
12	12.9985	12.9999	13.0021	0.234	0.100	10.7960	0.110	0.107	13.0000	10.2000	0.357	11.0000	14.9215	14.9250	14.9294	1.5652	1.5677	1.5707
13	13.9985	13.9999	14.0022	0.235	0.100	11.7960	0.108	0.103	14.0000	11.2000	0.353	12.0000	15.8253	15.8289	15.8332	1.5651	1.5676	1.5706
14	14.9985	14.9999	15.0023	0.235	0.101	12.7960	0.105	0.099	15.0000	12.2000	0.350	13.0000	16.9328	16.9365	16.9409	1.5651	1.5676	1.5706
15	15.9985	15.9999	16.0024	0.236	0.102	13.7960	0.102	0.096	16.0000	13.2000	0.348	14.0000	17.8500	17.8537	17.8581	1.5651	1.5676	1.5706
16	16.9985	16.9999	17.0025	0.236	0.102	14.7960	0.100	0.093	17.0000	14.2000	0.345	15.0000	18.9421	18.9458	18.9503	1.5650	1.5675	1.5705
17	17.9985	17.9999	18.0026	0.236	0.103	15.7960	0.100	0.091	18.0000	15.2000	0.343	16.0000	19.8691	19.8729	19.8774	1.5650	1.5675	1.5705
18	18.9985	18.9999	19.0027	0.237	0.103	16.7960	0.100	0.089	19.0000	16.2000	0.341	17.0000	20.9497	20.9534	20.9579	1.5650	1.5675	1.5705
19	19.9985	19.9999	20.0028	0.237	0.103	17.7960	0.100	0.087	20.0000	17.2000	0.339	18.0000	21.8845	21.8883	21.8928	1.5649	1.5674	1.5704
20	20.9985	20.9999	21.0029	0.237	0.104	18.7960	0.100	0.085	21.0000	18.2000	0.338	19.0000	22.9559	22.9597	22.9643	1.5649	1.5674	1.5704
21	21.9985	21.9999	22.0030	0.237	0.104	19.7960	0.100	0.083	22.0000	19.2000	0.336	20.0000	23.8970	23.9009	23.9054	1.5648	1.5673	1.5703
22	22.9985	22.9999	23.0031	0.237	0.104	20.7960	0.100	0.082	23.0000	20.2000	0.334	21.0000	24.9612	24.9650	24.9696	1.5648	1.5673	1.5703
23	23.9985	23.9999	24.0032	0.238	0.104	21.7960	0.100	0.081	24.0000	21.2000	0.333	22.0000	25.9075	25.9114	25.9160	1.5648	1.5673	1.5703
24	24.9985	24.9999	25.0033	0.238	0.105	22.7960	0.100	0.080	25.0000	22.2000	0.332	23.0000	26.9657	26.9696	26.9743	1.5647	1.5672	1.5702
25	25.9985	25.9999	26.0034	0.238	0.105	23.7960	0.100	0.079	26.0000	23.2000	0.331	24.0000	27.9164	27.9203	27.9250	1.5647	1.5672	1.5702
26	26.9985	26.9999	27.0035	0.238	0.105	24.7960	0.100	0.078	27.0000	24.2000	0.330	25.0000	28.9698	28.9737	28.9784	1.5647	1.5672	1.5702
27	27.9985	27.9999	28.0036	0.239	0.105	25.7960	0.100	0.077	28.0000	25.2000	0.330	26.0000	29.9240	29.9279	29.9326	1.5646	1.5671	1.5701
28	28.9985	28.9999	29.0037	0.239	0.105	26.7960	0.100	0.076	29.0000	26.2000	0.329	27.0000	30.9732	30.9771	30.9818	1.5646	1.5671	1.5701
29	29.9985	29.9999	30.0038	0.239	0.106	27.7960	0.100	0.075	30.0000	27.2000	0.328	28.0000	31.9307	31.9347	31.9394	1.5646	1.5671	1.5701
30	30.9985	30.9999	31.0039	0.239	0.106	28.7960	0.100	0.074	31.0000	28.2000	0.327	29.0000	32.9763	32.9802	32.9849	1.5645	1.5670	1.5700
31	31.9985	31.9999	32.0040	0.239	0.106	29.7960	0.100	0.074	32.0000	29.2000	0.327	30.0000	33.9365	33.9405	33.9452	1.5645	1.5670	1.5700
32	32.9985	32.9999	33.0041	0.239	0.106	30.7960	0.100	0.073	33.0000	30.2000	0.326	31.0000	34.9789	34.9828	34.9876	1.5644	1.5669	1.5699
33	33.9985	33.9999	34.0042	0.239	0.106	31.7960	0.100	0.072	34.0000	31.2000	0.326	32.0000	35.9415	35.9455	35.9503	1.5644	1.5669	1.5699
34	34.9985	34.9999	35.0043	0.239	0.106	32.7960	0.100	0.072	35.0000	32.2000	0.325	33.0000	36.9814	36.9854	36.9902	1.5644	1.5669	1.5699
35	35.9985	35.9999	36.0044	0.239	0.106	33.7960	0.100	0.071	36.0000	33.2000	0.325	34.0000	37.9461	37.9501	37.9549	1.5643	1.5668	1.5698
36	36.9985	36.9999	37.0045	0.240	0.106	34.7960	0.100	0.071	37.0000	34.2000	0.324	35.0000	38.9835	38.9875	38.9923	1.5643	1.5668	1.5698
37	37.9985	37.9999	38.0046	0.240	0.107	35.7960	0.100	0.070	38.0000	35.2000	0.324	36.0000	39.9503	39.9543	39.9591	1.5643	1.5668	1.5698
38	38.9985	38.9999	39.0047	0.240	0.107	36.7960	0.100	0.070	39.0000	36.2000	0.323	37.0000	40.9854	40.9894	40.9942	1.5642	1.5667	1.5697
39	39.9985	39.9999	40.0048	0.240	0.107	37.7960	0.100	0.069	40.0000	37.2000	0.323	38.0000	41.9539	41.9579	41.9627	1.5642	1.5667	1.5697
40	40.9985	40.9999	41.0049	0.240	0.107	38.7960	0.100	0.069	41.0000	38.2000	0.323	39.0000	42.9874	42.9914	42.9962	1.5642	1.5667	1.5697
41	41.9985	41.9999	42.0050	0.240	0.107	39.7960	0.100	0.069	42.0000	39.2000	0.322	40.0000	43.9572	43.9612	43.9661	1.5641	1.5666	1.5696
42	42.9985	42.9999	43.0051	0.240	0.107	40.7960	0.100	0.068	43.0000	40.2000	0.322	41.0000	44.9888	44.9928	44.9927	1.5641	1.5666	1.5696
43	43.9985	43.9999	44.0052	0.240	0.107	41.7960	0.100	0.068	44.0000	41.2000	0.322	42.0000	45.9603	45.9643	45.9692	1.5641	1.5666	1.5696
44	44.9985	44.9999	45.0053	0.240	0.107	42.7960	0.100	0.068	45.0000	42.2000	0.322	43.0000	46.9903	46.9943	46.9992	1.5640	1.5665	1.5695
45	45.9985	45.9999	46.0054	0.240	0.107	43.7960	0.100	0.067	46.0000	43.2000	0.321	44.0000	47.9630	47.9670	47.9719	1.5640	1.5665	1.5695
46	46.9985	46.9999	47.0055	0.240	0.107	44.7960	0.100	0.067	47.0000	44.2000	0.321	45.0000	48.9916	48.9957	49.0005	1.5639	1.5664	1.5694
47	47.9985	47.9999	48.0056	0.240	0.107	45.7960	0.100	0.067	48.0000	45.2000	0.320	46.0000	49.9654	49.9694	49.9743	1.5639	1.5664	1.5694
48	48.9985	48.9999	49.0057	0.240	0.107	46.7960	0.100	0.066	49.0000	46.2000	0.320	47.0000	50.9929	50.9969	51.0018	1.5639	1.5664	1.5694
49	49.9985	49.9999	50.0058	0.240	0.107	47.7960	0.100	0.066	50.0000	47.2000	0.320	48.0000	51.9676	51.9717	51.9766	1.5638	1.5663	1.5693
50	50.9985	50.9999	51.0059	0.240	0.107	48.7960	0.100	0.066	51.0000	48.2000	0.319	49.0000	52.9940	52.9981	53.0030	1.5638	1.5663	1.5693

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 5a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 6a—*2.5/5 Diametral Pitch, Internal*[a]

2.5/5 Diametral Pitch
Pressure Angle, 30°

Addendum (Basic), 0.2000
Dedendum (See Sec 6)

Circular Pitch, 1.2566
Meas-Pin Diam, 0.5760

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit				All fits	
					Flat-Root Side Fit										Space width
						Major-diam Fillet		Major diam						Measurement between pins	
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad		Min effective 0.6283
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance⟶			$+0.0607 + L^d$ -0.0000	Min	$+0.0050$ -0.0000	App	Max	$+0.0450$ -0.0000	$+0.0007 + L^d$ $-(0.0007 + L)$	Min	$+0.0050$ -0.0000	$+0.0450$ -0.0000	Min[e]	Max	Dimensional Max[f]
6	2.4000	2.0785	2.8000	2.759	2.0885	0.058	0.021	2.8840	2.8000	2.8000	2.0885	3.1200	0.063	1.7655	0.6326
7	2.8000	2.4249	3.2000	3.153	2.4349	0.064	0.024	3.2840	3.2000	3.2000	2.4349	3.5200	0.075	2.0971	0.6326
8	3.2000	2.7713	3.6000	3.549	2.8300	0.068	0.026	3.6840	3.6000	3.6000	2.8300	3.9200	0.081	2.5662	0.6326
9	3.6000	3.1177	4.0000	3.945	3.2000	0.071	0.028	4.0840	4.0000	4.0000	3.2000	4.3200	0.086	2.9125	0.6326
10	4.0000	3.4641	4.4000	4.341	3.6000	0.073	0.030	4.4840	4.4000	4.4000	3.6000	4.7200	0.090	3.3666	0.6327
11	4.4000	3.8105	4.8000	4.739	4.0000	0.075	0.031	4.8840	4.8000	4.8000	4.0000	5.1200	0.093	3.7226	0.6327
12	4.8000	4.1569	5.2000	5.135	4.4000	0.077	0.033	5.2840	5.2000	5.2000	4.4000	5.5200	0.096	4.1669	0.6327
13	5.2000	4.5033	5.6000	5.533	4.8000	0.078	0.034	5.6840	5.6000	5.6000	4.8000	5.9200	0.098	4.5295	0.6327
14	5.6000	4.8498	6.0000	5.933	5.2000	0.079	0.034	6.0840	6.0000	6.0000	5.2000	6.3200	0.100	4.9670	0.6327
15	6.0000	5.1962	6.4000	6.331	5.6000	0.080	0.035	6.4840	6.4000	6.4000	5.6000	6.7200	0.101	5.3345	0.6327
16	6.4000	5.5426	6.8000	6.729	6.0000	0.081	0.036	6.8840	6.8000	6.8000	6.0000	7.1200	0.102	5.7672	0.6327
17	6.8000	5.8890	7.2000	7.129	6.4000	0.082	0.036	7.2840	7.2000	7.2000	6.4000	7.5200	0.104	6.1386	0.6328
18	7.2000	6.2354	7.6000	7.527	6.8000	0.083	0.037	7.6840	7.6000	7.6000	6.8000	7.9200	0.105	6.5674	0.6328
19	7.6000	6.5818	8.0000	7.927	7.2000	0.083	0.037	8.0840	8.0000	8.0000	7.2000	8.3200	0.106	6.9417	0.6328
20	8.0000	6.9282	8.4000	8.325	7.6000	0.084	0.038	8.4840	8.4000	8.4000	7.6000	8.7200	0.106	7.3675	0.6328
21	8.4000	7.2746	8.8000	8.726	8.0000	0.084	0.038	8.8840	8.8000	8.8000	8.0000	9.1200	0.107	7.7442	0.6328
22	8.8000	7.6210	9.2000	9.124	8.4000	0.085	0.039	9.2840	9.2000	9.2000	8.4000	9.5200	0.108	8.1676	0.6328
23	9.2000	7.9674	9.6000	9.524	8.8000	0.085	0.039	9.6840	9.6000	9.6000	8.8000	9.9200	0.108	8.5464	0.6329
24	9.6000	8.3138	10.0000	9.924	9.2000	0.085	0.039	10.0840	10.0000	10.0000	9.2000	10.3200	0.109	8.9677	0.6329
25	10.0000	8.6602	10.4000	10.322	9.6000	0.086	0.040	10.4840	10.4000	10.4000	9.6000	10.7200	0.109	9.3481	0.6329
26	10.4000	9.0067	10.8000	10.722	10.0000	0.086	0.040	10.8840	10.8000	10.8000	10.0000	11.1200	0.110	9.7678	0.6329
27	10.8000	9.3531	11.2000	11.122	10.4000	0.086	0.040	11.2840	11.2000	11.2000	10.4000	11.5200	0.110	10.1496	0.6329
28	11.2000	9.6995	11.6000	11.522	10.8000	0.086	0.040	11.6840	11.6000	11.6000	10.8000	11.9200	0.110	10.5678	0.6329
29	11.6000	10.0459	12.0000	11.922	11.2000	0.087	0.040	12.0840	12.0000	12.0000	11.2000	12.3200	0.111	10.9511	0.6330
30	12.0000	10.3923	12.4000	12.320	11.6000	0.087	0.041	12.4840	12.4000	12.4000	11.6000	12.7200	0.111	11.3681	0.6330
31	12.4000	10.7387	12.8000	12.720	12.0000	0.087	0.041	12.8840	12.8000	12.8000	12.0000	13.1200	0.111	11.7523	0.6330
32	12.8000	11.0851	13.2000	13.120	12.4000	0.087	0.041	13.2840	13.2000	13.2000	12.4000	13.5200	0.112	12.1681	0.6330
33	13.2000	11.4315	13.6000	13.520	12.8000	0.087	0.041	13.6840	13.6000	13.6000	12.8000	13.9200	0.112	12.5532	0.6330
34	13.6000	11.7780	14.0000	13.920	13.2000	0.088	0.041	14.0840	14.0000	14.0000	13.2000	14.3200	0.113	12.9681	0.6330
35	14.0000	12.1244	14.4000	14.318	13.6000	0.088	0.042	14.4840	14.4000	14.4000	13.6000	14.7200	0.113	13.3541	0.6330
36	14.4000	12.4708	14.8000	14.718	14.0000	0.088	0.042	14.8840	14.8000	14.8000	14.0000	15.1200	0.113	13.7682	0.6331
37	14.8000	12.8172	15.2000	15.118	14.4000	0.088	0.042	15.2840	15.2000	15.2000	14.4000	15.5200	0.113	14.1550	0.6331
38	15.2000	13.1636	15.6000	15.518	14.8000	0.088	0.042	15.6840	15.6000	15.6000	14.8000	15.9200	0.114	14.5682	0.6331
39	15.6000	13.5100	16.0000	15.918	15.2000	0.088	0.042	16.0840	16.0000	16.0000	15.2000	16.3200	0.114	14.9557	0.6331
40	16.0000	13.8564	16.4000	16.318	15.6000	0.088	0.042	16.4840	16.4000	16.4000	15.6000	16.7200	0.114	15.3683	0.6331
41	16.4000	14.2028	16.8000	16.718	16.0000	0.088	0.042	16.8840	16.8000	16.8000	16.0000	17.1200	0.114	15.7563	0.6331
42	16.8000	14.5492	17.2000	17.118	16.4000	0.089	0.042	17.2840	17.2000	17.2000	16.4000	17.5200	0.114	16.1685	0.6332
43	17.2000	14.8956	17.6000	17.518	16.8000	0.089	0.042	17.6840	17.6000	17.6000	16.8000	17.9200	0.114	16.5571	0.6332
44	17.6000	15.2420	18.0000	17.918	17.2000	0.089	0.042	18.0840	18.0000	18.0000	17.2000	18.3200	0.114	16.9685	0.6332
45	18.0000	15.5884	18.4000	18.318	17.6000	0.089	0.042	18.4840	18.4000	18.4000	17.6000	18.7200	0.115	17.3576	0.6332
46	18.4000	15.9349	18.8000	18.717	18.0000	0.089	0.043	18.8840	18.8000	18.8000	18.0000	19.1200	0.115	17.7685	0.6332
47	18.8000	16.2813	19.2000	19.117	18.4000	0.089	0.043	19.2840	19.2000	19.2000	18.4000	19.5200	0.115	18.1581	0.6332
48	19.2000	16.6277	19.6000	19.517	18.8000	0.089	0.043	19.6840	19.6000	19.6000	18.8000	19.9200	0.115	18.5686	0.6332
49	19.6000	16.9741	20.0000	19.917	19.2000	0.089	0.043	20.0840	20.0000	20.0000	19.2000	20.3200	0.115	18.9586	0.6333
50	20.0000	17.3205	20.4000	20.317	19.6000	0.089	0.043	20.4840	20.4000	20.4000	19.6000	20.7200	0.115	19.3687	0.6333

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] $L = 0.0001 \times$ diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 6b—*2.5/5 Diametral Pitch, External*[a]

2.5/5 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.2000 Dedendum (See Sec 6)	Circular Pitch, 1.2566 Meas-Pin Diam, 0.7680

EXTERNAL

N	Major-diameter fit[b]																	
	Major diameter			Major-diam chamfer		Flat-root side fit			Fillet root[c]			Dimensions for all fits						
						Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Tooth thickness		
																Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.6278	0.6298	0.6325
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J°)	+0.0000 −(0.0006 + J°)	+0.0809 + J° −0.0000	App	Min	+0.0000 −0.0450	App	Max	+0.0000 −0.0100	+0.0000 −0.0450	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	2.7985	2.7999	2.8011	0.091	0.036	1.9160	0.068	0.067	2.8000	1.6800	—	2.0885	3.5400	3.5433	3.5468	0.6234	0.6259	0.6286
7	3.1985	3.1999	3.2011	0.092	0.037	2.3160	0.060	0.060	3.2000	2.0800	—	2.4349	3.8664	3.8697	3.8732	0.6234	0.6259	0.6286
8	3.5985	3.5999	3.6012	0.092	0.038	2.7160	0.056	0.055	3.6000	2.4800	0.159	2.8300	4.3511	4.3545	4.3582	0.6234	0.6259	0.6286
9	3.9985	3.9999	4.0012	0.093	0.039	3.1160	0.052	0.051	4.0000	2.8800	0.149	3.2000	4.6947	4.6981	4.7018	0.6234	0.6259	0.6286
10	4.3985	4.3999	4.4012	0.093	0.039	3.5160	0.048	0.048	4.4000	3.2800	0.146	3.6000	5.1589	5.1624	5.1662	0.6234	0.6259	0.6286
11	4.7985	4.7999	4.8013	0.094	0.039	3.9160	0.046	0.045	4.8000	3.6800	0.144	4.0000	5.5132	5.5167	5.5205	0.6234	0.6259	0.6286
12	5.1985	5.1999	5.2013	0.094	0.040	4.3160	0.044	0.043	5.2000	4.0800	0.142	4.4000	5.9648	5.9683	5.9722	0.6234	0.6259	0.6286
13	5.5985	5.5999	5.6014	0.094	0.040	4.7160	0.043	0.041	5.6000	4.4800	0.141	4.8000	6.3262	6.3298	6.3337	0.6233	0.6258	0.6285
14	5.9985	5.9999	6.0014	0.094	0.040	5.1160	0.042	0.040	6.0000	4.8800	0.139	5.2000	6.7692	6.7728	6.7768	0.6233	0.6258	0.6285
15	6.3985	6.3999	6.4014	0.084	0.040	5.5160	0.041	0.038	6.4000	5.2800	0.138	5.6000	7.1360	7.1397	7.1437	0.6233	0.6258	0.6285
16	6.7985	6.7999	6.8015	0.094	0.040	5.9160	0.040	0.037	6.8000	5.6800	0.137	6.0000	7.5729	7.5766	7.5806	0.6233	0.6258	0.6285
17	7.1985	7.1999	7.2015	0.094	0.041	6.3160	0.040	0.036	7.2000	6.0800	0.137	6.4000	7.9436	7.9474	7.9514	0.6233	0.6258	0.6285
18	7.5985	7.5999	7.6016	0.095	0.041	6.7160	0.040	0.035	7.6000	6.4800	0.136	6.8000	8.3759	8.3796	8.3837	0.6233	0.6258	0.6285
19	7.9985	7.9999	8.0016	0.095	0.041	7.1160	0.040	0.035	8.0000	6.8800	0.135	7.2000	8.7498	8.7536	8.7577	0.6233	0.6258	0.6285
20	8.3985	8.3999	8.4016	0.095	0.041	7.5160	0.040	0.034	8.4000	7.2800	0.134	7.6000	9.1784	9.1822	9.1863	0.6233	0.6258	0.6285
21	8.7985	8.7999	8.8017	0.095	0.042	7.9160	0.040	0.033	8.8000	7.6800	0.134	8.0000	9.5547	9.5585	9.5627	0.6232	0.6257	0.6284
22	9.1985	9.1999	9.2017	0.095	0.042	8.3160	0.040	0.033	9.2000	8.0800	0.133	8.4000	9.9804	9.9842	9.9884	0.6232	0.6257	0.6284
23	9.5985	9.5999	9.6018	0.095	0.042	8.7160	0.040	0.032	9.6000	8.4800	0.133	8.8000	10.3588	10.3627	10.3669	0.6232	0.6257	0.6284
24	9.9985	9.9999	10.0018	0.095	0.042	9.1160	0.040	0.032	10.0000	8.8800	0.132	9.2000	10.7822	10.7861	10.7903	0.6232	0.6257	0.6284
25	10.3985	10.3999	10.4018	0.095	0.042	9.5160	0.040	0.031	10.4000	9.2800	0.132	9.6000	11.1625	11.1644	11.1706	0.6232	0.6257	0.6284
26	10.7985	10.7999	10.8019	0.095	0.042	9.9160	0.040	0.031	10.8000	9.6800	0.131	10.0000	11.5837	11.5876	11.5919	0.6232	0.6257	0.6284
27	11.1985	11.1999	11.2019	0.096	0.042	10.3160	0.040	0.031	11.2000	10.0800	0.131	10.4000	11.9655	11.9694	11.9737	0.6232	0.6257	0.6284
28	11.5985	11.5999	11.6020	0.096	0.042	10.7160	0.040	0.030	11.6000	10.4800	0.131	10.8000	12.3852	12.3891	12.3934	0.6232	0.6257	0.6284
29	11.9985	11.9999	12.0020	0.096	0.042	11.1160	0.040	0.030	12.0000	10.8800	0.130	11.2000	12.7682	12.7721	12.7764	0.6232	0.6257	0.6284
30	12.3985	12.3999	12.4020	0.096	0.042	11.5160	0.040	0.030	12.4000	11.2800	0.130	11.6000	13.1863	13.1902	13.1945	0.6231	0.6256	0.6283
31	12.7985	12.7999	12.8021	0.096	0.042	11.9160	0.040	0.029	12.8000	11.6800	0.130	12.0000	13.5704	13.5743	13.5786	0.6231	0.6256	0.6283
32	13.1985	13.1999	13.2021	0.096	0.042	12.3160	0.040	0.029	13.2000	12.0800	0.129	12.4000	13.9874	13.9913	13.9956	0.6231	0.6256	0.6283
33	13.5985	13.5999	13.6022	0.096	0.042	12.7160	0.040	0.029	13.6000	12.4800	0.129	12.8000	14.3724	14.3764	14.3807	0.6231	0.6256	0.6283
34	13.9985	13.9999	14.0022	0.096	0.042	13.1160	0.040	0.029	14.0000	12.8800	0.129	13.2000	14.7883	14.7923	14.7966	0.6231	0.6256	0.6283
35	14.3985	14.3999	14.4022	0.096	0.043	13.5160	0.040	0.029	14.4000	13.2800	0.129	13.6000	15.1733	15.1783	15.1826	0.6231	0.6256	0.6283
36	14.7985	14.7999	14.8023	0.096	0.043	13.9160	0.040	0.028	14.8000	13.6800	0.129	14.0000	15.5893	15.5933	15.5976	0.6231	0.6256	0.6283
37	15.1985	15.1999	15.2023	0.096	0.043	14.3160	0.040	0.028	15.2000	14.0800	0.128	14.4000	15.9760	15.9800	15.9843	0.6231	0.6256	0.6283
38	15.5985	15.5999	15.6024	0.096	0.043	14.7160	0.040	0.028	15.6000	14.4800	0.128	14.8000	16.3899	16.3939	16.3982	0.6230	0.6255	0.6282
39	15.9985	15.9999	16.0024	0.096	0.043	15.1160	0.040	0.028	16.0000	14.8800	0.128	15.2000	16.7773	16.7813	16.7856	0.6230	0.6255	0.6282
40	16.3985	16.3999	16.4024	0.096	0.043	15.5160	0.040	0.028	16.4000	15.2800	0.128	15.6000	17.1907	17.1947	17.1990	0.6230	0.6255	0.6282
41	16.7985	16.7999	16.8025	0.096	0.043	15.9160	0.040	0.027	16.8000	15.6800	0.128	16.0000	17.5787	17.5827	17.5870	0.6230	0.6255	0.6282
42	17.1985	17.1999	17.2025	0.096	0.043	16.3160	0.040	0.027	17.2000	16.0800	0.127	16.4000	17.9912	17.9953	17.9996	0.6230	0.6255	0.6282
43	17.5985	17.5999	17.6026	0.096	0.043	16.7160	0.040	0.027	17.6000	16.4800	0.127	16.8000	18.3798	18.3839	18.3882	0.6230	0.6255	0.6282
44	17.9985	17.9999	18.0026	0.096	0.043	17.1160	0.040	0.027	18.0000	16.8800	0.127	17.2000	18.7919	18.7960	18.8003	0.6230	0.6255	0.6282
45	18.3985	18.3999	18.4026	0.096	0.043	17.5160	0.040	0.027	18.4000	17.2800	0.127	17.6000	19.1810	19.1851	19.1894	0.6230	0.6255	0.6282
46	18.7985	18.7999	18.8027	0.096	0.043	17.9160	0.040	0.027	18.8000	17.6800	0.127	18.0000	19.5923	19.5964	19.6008	0.6229	0.6254	0.6281
47	19.1985	19.1999	19.2027	0.096	0.043	18.3160	0.040	0.027	19.2000	18.0800	0.127	18.4000	19.9818	19.9859	19.9903	0.6229	0.6254	0.6281
48	19.5985	19.5999	19.6028	0.096	0.043	18.7160	0.040	0.027	19.6000	18.4800	0.127	18.8000	20.3928	20.3969	20.4013	0.6229	0.6254	0.6281
49	19.9985	19.9999	20.0028	0.096	0.043	19.1160	0.040	0.027	20.0000	18.8800	0.126	19.2000	20.7828	20.7869	20.7913	0.6229	0.6254	0.6281
50	20.3985	20.3999	20.4028	0.096	0.043	19.5160	0.040	0.026	20.4000	19.2800	0.126	19.6000	21.1934	21.1975	21.2019	0.6229	0.6254	0.6281

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 6a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27) except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 7a—*3/6 Diametral Pitch, Internal*[a]

3/6 Diametral Pitch, Pressure Angle, 30° | Addendum (Basic), 0.1667, Dedendum (See Sec 6) | Circular Pitch, 1.0472, Meas-Pin Diam, 0.4800

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits		
					Flat-Root Side Fit									Measurement between pins	Space width
						Major-diam fillet		Major diam							
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad		Min effective 0.5236
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance⟶			+0.0007 + Ld −0.0000	Min	+0.0050 −0.0000	App	Max	+0.0383 −0.0000	+0.0007 + Ld −(0.0007 + L)	Min	+0.0050 −0.0000	+0.0383 −0.0000	Min[c]	Max	Dimensional Max[f]
6	2.0000	1.7321	2.3333	2.300	1.7421	0.048	0.017	2.4040	2.3333	2.3333	1.7421	2.6000	0.053	1.4722	0.5277
7	2.3333	2.0207	2.6667	2.628	2.0307	0.053	0.020	2.7373	2.6667	2.6667	2.0307	2.9333	0.062	1.7485	0.5277
8	2.6667	2.3094	3.0000	2.957	2.3633	0.057	0.022	3.0707	3.0000	3.0000	2.3633	3.2667	0.067	2.1394	0.5277
9	3.0000	2.5981	3.3333	3.286	2.6667	0.059	0.024	3.4040	3.3333	3.3333	2.6667	3.6000	0.071	2.4280	0.5277
10	3.3333	2.8868	3.6667	3.618	3.0000	0.061	0.025	3.7373	3.6667	3.6667	3.0000	3.9333	0.074	2.8064	0.5277
11	3.6667	3.1754	4.0000	3.949	3.3333	0.063	0.026	4.0707	4.0000	4.0000	3.3333	4.2667	0.077	3.1030	0.5277
12	4.0000	3.4641	4.3333	4.280	3.6667	0.064	0.027	4.4040	4.3333	4.3333	3.6667	4.6000	0.080	3.4734	0.5278
13	4.3333	3.7528	4.6667	4.612	4.0000	0.065	0.028	4.7373	4.6667	4.6667	4.0000	4.9333	0.081	3.7755	0.5278
14	4.6667	4.0415	5.0000	4.943	4.3333	0.066	0.029	5.0707	5.0000	5.0000	4.3333	5.2667	0.083	4.1401	0.5278
15	5.0000	4.3301	5.3333	5.277	4.6667	0.067	0.029	5.4040	5.3333	5.3333	4.6667	5.6000	0.084	4.4464	0.5278
16	5.3333	4.6188	5.6667	5.608	5.0000	0.068	0.030	5.7373	5.6667	5.6667	5.0000	5.9333	0.085	4.8069	0.5278
17	5.6667	4.9075	6.0000	5.941	5.3333	0.068	0.030	6.0707	6.0000	6.0000	5.3333	6.2667	0.086	5.1164	0.5278
18	6.0000	5.1962	6.3333	6.273	5.6667	0.069	0.031	6.4040	6.3333	6.3333	5.6667	6.6000	0.087	5.4737	0.5278
19	6.3333	5.4848	6.6667	6.606	6.0000	0.069	0.031	6.7373	6.6667	6.6667	6.0000	6.9333	0.088	5.7857	0.5279
20	6.6667	5.7735	7.0000	6.937	6.3333	0.070	0.032	7.0707	7.0000	7.0000	6.3333	7.2667	0.088	6.1405	0.5279
21	7.0000	6.0622	7.3333	7.271	6.6667	0.070	0.032	7.4040	7.3333	7.3333	6.6667	7.6000	0.089	6.4544	0.5279
22	7.3333	6.3509	7.6667	7.604	7.0000	0.071	0.032	7.7373	7.6667	7.6667	7.0000	7.9333	0.089	6.8072	0.5279
23	7.6667	6.6395	8.0000	7.938	7.3333	0.071	0.032	8.0707	8.0000	8.0000	7.3333	8.2667	0.090	7.1228	0.5279
24	8.0000	6.9282	8.3333	8.269	7.6667	0.071	0.033	8.4040	8.3333	8.3333	7.6667	8.6000	0.090	7.4740	0.5279
25	8.3333	7.2169	8.6667	8.602	8.0000	0.071	0.033	8.7373	8.6667	8.6667	8.0000	8.9333	0.091	7.7910	0.5279
26	8.6667	7.5056	9.0000	8.936	8.3333	0.072	0.033	9.0707	9.0000	9.0000	8.3333	9.2667	0.091	8.1407	0.5279
27	9.0000	7.7942	9.3333	9.269	8.6667	0.072	0.033	9.4040	9.3333	9.3333	8.6667	9.6000	0.092	8.4591	0.5280
28	9.3333	8.0829	9.6667	9.600	9.0000	0.072	0.034	9.7373	9.6667	9.6667	9.0000	9.9333	0.092	8.8076	0.5280
29	9.6667	8.3716	10.0000	9.934	9.3333	0.072	0.034	10.0707	10.0000	10.0000	9.3333	10.2667	0.092	9.1267	0.5280
30	10.0000	8.6603	10.3333	10.267	9.6667	0.072	0.034	10.4040	10.3333	10.3333	9.6667	10.6000	0.092	9.4743	0.5280
31	10.3333	8.9489	10.6667	10.601	10.0000	0.073	0.034	10.7373	10.6667	10.6667	10.0000	10.9333	0.093	9.7943	0.5280
32	10.6667	9.2376	11.0000	10.934	10.3333	0.073	0.034	11.0707	11.0000	11.0000	10.3333	11.2667	0.093	10.1409	0.5280
33	11.0000	9.5263	11.3333	11.267	10.6667	0.073	0.034	11.4040	11.3333	11.3333	10.6667	11.6000	0.093	10.4618	0.5280
34	11.3333	9.8150	11.6667	11.601	11.0000	0.073	0.034	11.7373	11.6667	11.6667	11.0000	11.9333	0.093	10.8075	0.5280
35	11.6667	10.1036	12.0000	11.932	11.3333	0.073	0.035	12.0707	12.0000	12.0000	11.3333	12.2667	0.094	11.1294	0.5281
36	12.0000	10.3923	12.3333	12.265	11.6667	0.073	0.035	12.4040	12.3333	12.3333	11.6667	12.6000	0.094	11.4744	0.5281
37	12.3333	10.6810	12.6667	12.599	12.0000	0.073	0.035	12.7373	12.6667	12.6667	12.0000	12.9333	0.094	11.7967	0.5281
38	12.6667	10.9697	13.0000	12.932	12.3333	0.073	0.035	13.0707	13.0000	13.0000	12.3333	13.2667	0.094	12.1411	0.5291
39	13.0000	11.2583	13.3333	13.265	12.6667	0.074	0.035	13.4040	13.3333	13.3333	12.6667	13.6000	0.094	12.4640	0.5281
40	13.3333	11.5470	13.6667	13.599	13.0000	0.074	0.035	13.7373	13.6667	13.6667	13.0000	13.9333	0.094	12.8078	0.5281
41	13.6667	11.8357	14.0000	13.932	13.3333	0.074	0.035	14.0707	14.0000	14.0000	13.3333	14.2667	0.095	13.1312	0.5281
42	14.0000	12.1244	14.3333	14.265	13.6667	0.074	0.035	14.4040	14.3333	14.3333	13.6667	14.6000	0.095	13.4747	0.5282
43	14.3333	12.4130	14.6667	14.599	14.0000	0.074	0.035	14.7373	14.6667	14.6667	14.0000	14.9333	0.095	13.7985	0.5282
44	14.6667	12.7017	15.0000	14.932	14.3333	0.074	0.035	15.0707	15.0000	15.0000	14.3333	15.2667	0.095	14.1414	0.5282
45	15.0000	12.9904	15.3333	15.266	14.6667	0.074	0.035	15.4040	15.3333	15.3333	14.6667	15.6000	0.095	14.4656	0.5282
46	15.3333	13.2791	15.6667	15.597	15.0000	0.074	0.036	15.7373	15.6667	15.6667	15.0000	15.9333	0.095	14.8080	0.5282
47	15.6667	13.5677	16.0000	15.930	15.3333	0.074	0.036	16.0707	16.0000	16.0000	15.3333	16.2667	0.095	15.1326	0.5282
48	16.0000	13.8564	16.3333	16.264	15.6667	0.074	0.036	16.4040	16.3333	16.3333	15.6667	16.6000	0.095	15.4747	0.5282
49	16.3333	14.1451	16.6667	16.597	16.0000	0.074	0.036	16.7373	16.6667	16.6667	16.0000	16.9333	0.095	15.7996	0.5282
50	16.6667	14.4338	17.0000	16.930	16.3333	0.074	0.036	17.0707	17.0000	17.0000	16.3333	17.2667	0.095	16.1415	0.5283

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowance errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 7b—*3/6 Diametral Pitch, External*[a]

3/6 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.1667 Dedendum (See Sec 6)	Circular Pitch, 1.0472 Meas-Pin Diam, 0.6400

EXTERNAL

	Major-diameter fit[b]								Fillet root[c]			Dimensions for all fits						
						Flat-root side fit									Tooth thickness			
N	Major diameter			Major-diam chamfer		Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.5231	0.5251	0.5278
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J^e)	+0.0000 −(0.0006 + J^e)	+0.0009 + J^e −0.0000	App	Min	+0.0000 −0.0383	App	Max	+0.0000 −0.0100	+0.0000 −0.0383	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	2.3318	2.3332	2.3343	0.076	0.030	1.5960	0.057	0.056	2.3333	1.4000	—	1.7421	2.9490	2.9523	2.9558	0.5188	0.5213	0.5240
7	2.6652	2.6666	2.6677	0.077	0.031	1.9293	0.050	0.050	2.6667	1.7333	—	2.0307	3.2210	3.2243	3.2278	0.5188	0.5213	0.5240
8	2.9985	2.9999	3.0011	0.077	0.032	2.2627	0.047	0.046	3.0000	2.0667	0.135	2.3633	3.6250	3.6284	3.6320	0.5188	0.5213	0.5240
9	3.3318	3.3332	3.3344	0.077	0.032	2.5960	0.043	0.042	3.3333	2.4000	0.124	2.6667	3.9113	3.9147	3.9183	0.5188	0.5213	0.5240
10	3.6652	3.6666	3.6678	0.078	0.033	2.9293	0.040	0.040	3.6667	2.7333	0.122	3.0000	4.2981	4.3016	4.3054	0.5188	0.5213	0.5240
11	3.9985	3.9999	4.0012	0.078	0.033	3.2627	0.039	0.038	4.0000	3.0667	0.120	3.3333	4.5933	4.5969	4.6007	0.5188	0.5213	0.5240
12	4.3318	4.3332	4.3345	0.078	0.033	3.5960	0.037	0.036	4.3333	3.4000	0.119	3.6667	4.9696	4.9732	4.9771	0.5188	0.5213	0.5240
13	4.6652	4.6666	4.6679	0.078	0.033	3.9293	0.036	0.034	4.6667	3.7333	0.117	4.0000	5.2709	5.2745	5.2784	0.5188	0.5213	0.5240
14	4.9985	4.9999	5.0013	0.078	0.034	4.2627	0.035	0.033	5.0000	4.0667	0.116	4.3333	5.6401	5.6437	5.6477	0.5188	0.5213	0.5240
15	5.3318	5.3332	5.3346	0.079	0.034	4.5960	0.034	0.032	5.3333	4.4000	0.115	4.6667	5.9457	5.9494	5.9534	0.5188	0.5213	0.5240
16	5.6652	5.6666	5.6680	0.079	0.034	4.9293	0.033	0.031	5.6667	4.7333	0.114	5.0000	6.3098	6.3135	6.3175	0.5188	0.5213	0.5240
17	5.9985	5.9999	6.0014	0.079	0.034	5.2627	0.033	0.030	6.0000	5.0667	0.114	5.3333	6.6186	6.6223	6.6263	0.5187	0.5212	0.5239
18	6.3318	6.3332	6.3347	0.079	0.034	5.5960	0.033	0.030	6.3333	5.4000	0.113	5.6667	6.9787	6.9825	6.9866	0.5187	0.5212	0.5239
19	6.6652	6.6666	6.6681	0.079	0.034	5.9293	0.033	0.029	6.6667	5.7333	0.112	6.0000	7.2904	7.2942	7.2983	0.5187	0.5212	0.5239
20	6.9985	6.9999	7.0015	0.079	0.035	6.2627	0.033	0.028	7.0000	6.0667	0.112	6.3333	7.6475	7.6513	7.6555	0.5187	0.5212	0.5239
21	7.3318	7.3332	7.3348	0.079	0.035	6.5960	0.033	0.028	7.3333	6.4000	0.111	6.6667	7.9612	7.9650	7.9692	0.5187	0.5212	0.5239
22	7.6652	7.6666	7.6682	0.079	0.035	6.9293	0.033	0.027	7.6667	6.7333	0.111	7.0000	8.3160	8.3198	8.3240	0.5187	0.5212	0.5239
23	7.9985	7.9999	8.0016	0.079	0.035	7.2627	0.033	0.027	8.0000	7.0667	0.110	7.3333	8.6313	8.6352	8.6394	0.5187	0.5212	0.5239
24	8.3318	8.3332	8.3349	0.079	0.035	7.5960	0.033	0.027	8.3333	7.4000	0.110	7.6667	8.9841	8.9880	8.9922	0.5187	0.5212	0.5239
25	8.6652	8.6666	8.6683	0.079	0.035	7.9293	0.033	0.026	8.6667	7.7333	0.109	8.0000	9.3010	9.3049	9.3091	0.5187	0.5212	0.5239
26	8.9985	8.9999	9.0017	0.079	0.035	8.2627	0.033	0.026	9.0000	8.0667	0.109	8.3333	9.6521	9.6561	9.6603	0.5187	0.5212	0.5239
27	9.3318	9.3332	9.3350	0.080	0.035	8.5960	0.033	0.026	9.3333	8.4000	0.109	8.6667	9.9702	9.9742	9.9784	0.5187	0.5212	0.5239
28	9.6652	9.6666	9.6684	0.080	0.035	8.9293	0.033	0.025	9.6667	8.7333	0.109	9.0000	10.3197	10.3237	10.3279	0.5186	0.5211	0.5238
29	9.9985	9.9999	10.0018	0.080	0.035	9.2627	0.033	0.025	10.0000	9.0667	0.108	9.3333	10.6389	10.6429	10.6471	0.5186	0.5211	0.5238
30	10.3318	10.3332	10.3351	0.080	0.035	9.5960	0.033	0.025	10.3333	9.4000	0.108	9.6667	10.9875	10.9915	10.9957	0.5186	0.5211	0.5238
31	10.6652	10.6666	10.6685	0.080	0.035	9.9293	0.033	0.025	10.6667	9.7333	0.108	10.0000	11.3076	11.3115	11.3158	0.5186	0.5211	0.5238
32	10.9985	10.9999	11.0019	0.080	0.035	10.2627	0.033	0.024	11.0000	10.0667	0.108	10.3333	11.6551	11.6590	11.6633	0.5196	0.5211	0.5238
33	11.3318	11.3332	11.3352	0.080	0.035	10.5960	0.033	0.024	11.3333	10.4000	0.107	10.6667	11.9760	11.9799	11.9842	0.5186	0.5211	0.5238
34	11.6652	11.6666	11.6686	0.080	0.035	10.9293	0.033	0.024	11.6667	10.7333	0.107	11.0000	12.3225	12.3265	12.3308	0.5186	0.5211	0.5238
35	11.9985	11.9999	12.0020	0.080	0.035	11.2627	0.033	0.024	12.0000	11.0667	0.107	11.3333	12.6442	12.6482	12.6525	0.5186	0.5211	0.5238
36	12.3318	12.3332	12.3353	0.080	0.035	11.5960	0.033	0.024	12.3333	11.4000	0.107	11.6667	12.9900	12.9940	12.9983	0.5186	0.5211	0.5238
37	12.6652	12.6666	12.6687	0.080	0.036	11.9293	0.033	0.023	12.6667	11.7333	0.107	12.0000	13.3122	13.3162	13.3205	0.5186	0.5211	0.5238
38	12.9985	12.9999	13.0021	0.080	0.036	12.2627	0.033	0.023	13.0000	12.0667	0.106	12.3333	13.6573	13.6613	13.6656	0.5186	0.5211	0.5238
39	13.3318	13.3332	13.3354	0.080	0.036	12.5960	0.033	0.023	13.3333	12.4000	0.106	12.6667	13.9800	13.9840	13.9884	0.5185	0.5210	0.5237
40	13.6652	13.6666	13.6688	0.080	0.036	12.9293	0.033	0.023	13.6667	12.7333	0.106	13.0000	14.3245	14.3285	14.3329	0.5185	0.5210	0.5237
41	13.9985	13.9999	14.0022	0.080	0.036	13.2627	0.033	0.023	14.0000	13.0667	0.106	13.3333	14.6478	14.6518	14.6562	0.5185	0.5210	0.5237
42	14.3318	14.3332	14.3355	0.080	0.036	13.5960	0.033	0 023	14.3333	13.4000	0.006	13.6667	14.9917	14.9957	15.0001	0.5185	0.5210	0.5237
43	14.6652	14.6666	14.6689	0.080	0.036	13.9293	0.033	0.023	14.6667	13.7333	0.106	14.0000	15.3155	15.3195	15.3239	0.5185	0.5210	0.5237
44	14.9985	14.9999	15.0023	0.080	0.036	14.2627	0.033	0.023	15.0000	14.0667	0.106	14.3333	15.6588	15.6629	15.6673	0.5185	0.5210	0.5237
45	15.3318	15.3332	15.3356	0.080	0.036	14.5960	0.033	0.022	15.3333	14.4000	0.105	14.6667	15.9830	15.9871	15.9915	0.5185	0.5210	0.5237
46	15.6652	15.6666	15.6690	0.080	0.036	14.9293	0.033	0.022	15.6667	14.7333	0.105	15.0000	16.3260	16.3301	16.3345	0.5185	0.5210	0.5237
47	15.9985	15.9999	16.0024	0.080	0.036	15.2627	0.033	0.022	16.0000	15.0067	0.105	15.3333	16.6506	16.6547	16.6591	0.5185	0.5210	0.5237
48	16.3318	16.3332	16.3357	0.080	0.036	15.5960	0.033	0.022	16.3333	15.4000	0.105	15.6667	16.9931	16.9972	17.0016	0.5185	0.5210	0.5237
49	16.6652	16.6666	16.6691	0.080	0.036	15.9293	0.033	0.022	16.6667	15.7333	0.105	16.0000	17.3180	17.3221	17.3265	0.5185	0.5210	0.5237
50	16.9985	16.9999	17.0025	0.080	0.036	16.2627	0.033	0.022	17.0000	16.0667	0.105	16.3333	17.6600	17.6641	17.6685	0.5184	0.5209	0.5236

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specificially agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 7a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 8a—*4/8 Diametral Pitch, Internal*[a]

4/8 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.1250 Dedendum (See Sec 6)	Circular Pitch, 0.7854 Meas-Pin Diam, 0.3600

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits	
					Flat-Root Side Fit										
						Major-diam fillet		Major diam						Measurement between pins	Space width
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad		Min effective 0.3927
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance⟶			+0.0007 + Ld −0.0000	Min	+0.0050 −0.0000	App	Max	+0.0300 −0.0000	+0.0007 + Ld −(0.0007 + L)	Min	+0.0050 −0.0000	+0.0300 −0.0000	Min[e]	Max	Dimensional Max[f]
6	1.5000	1.2991	1.7500	1.725	1.3091	0.036	0.013	1.8040	1.7500	1.7500	1.3091	1.9500	0.038	1.1055	0.3965
7	1.7500	1.5156	2.0000	1.977	1.5256	0.040	0.015	2.0540	2.0000	2.0000	1.5256	2.2000	0.046	1.3127	0.3965
8	2.0000	1.7321	2.2500	2.219	1.7700	0.042	0.016	2.3040	2.2500	2.2500	1.7700	2.4500	0.050	1.6059	0.3965
9	2.2500	1.9486	2.5000	2.465	2.0000	0.044	0.018	2.5540	2.5000	2.5000	2.0000	2.7000	0.052	1.8224	0.3965
10	2.5000	2.1651	2.7500	2.713	2.2500	0.046	0.019	2.8040	2.7500	2.7500	2.2500	2.9500	0.055	2.1061	0.3965
11	2.7500	2.3816	3.0000	2.961	2.5000	0.047	0.020	3.0540	3.0000	3.0000	2.5000	3.2000	0.057	2.3285	0.3965
12	3.0000	2.5981	3.2500	3.211	2.7500	0.048	0.020	3.3040	3.2500	3.2500	2.7500	3.4500	0.059	2.6062	0.3965
13	3.2500	2.8146	3.5000	3.459	3.0000	0.049	0.021	3.5540	3.5000	3.5000	3.0000	3.7000	0.060	2.8328	0.3965
14	3.5000	3.0311	3.7500	3.707	3.2500	0.050	0.022	3.8040	3.7500	3.7500	3.2500	3.9500	0.061	3.1063	0.3965
15	3.7500	3.2476	4.0000	3.957	3.5000	0.050	0.022	4.0540	4.0000	4.0000	3.5000	4.2000	0.062	3.3360	0.3965
16	4.0000	3.4641	4.2500	4.207	3.7500	0.051	0.022	4.3040	4.2500	4.2500	3.7500	4.4500	0.063	3.6066	0.3966
17	4.2500	3.6806	4.5000	4.455	4.0000	0.051	0.023	4.5540	4.5000	4.5000	4.0000	4.7000	0.064	3.8385	0.3966
18	4.5000	3.8971	4.7500	4.705	4.2500	0.052	0.023	4.8040	4.7500	4.7500	4.2500	4.9500	0.065	4.1065	0.3966
19	4.7500	4.1136	5.0000	4.955	4.5000	0.052	0.023	5.0540	5.0000	5.0000	4.5000	5.2000	0.065	4.3405	0.3966
20	5.0000	4.3301	5.2500	5.203	4.7500	0.052	0.024	5.3040	5.2500	5.2500	4.7500	5.4500	0.066	4.6066	0.3966
21	5.2500	4.5466	5.5000	5.453	5.0000	0.053	0.024	5.5540	5.5000	5.5000	5.0000	5.7000	0.066	4.8420	0.3966
22	5.5000	4.7632	5.7500	5.703	5.2500	0.053	0.024	5.8040	5.7500	5.7500	5.2500	5.9500	0.067	5.1066	0.3966
23	5.7500	4.9797	6.0000	5.953	5.5000	0.053	0.024	6.0540	6.0000	6.0000	5.5000	6.2000	0.067	5.3433	0.3966
24	6.0000	5.1962	6.2500	6.201	5.7500	0.053	0.025	6.3040	6.2500	6.2500	5.7500	6.4500	0.068	5.6067	0.3966
25	6.2500	5.4127	6.5000	6.451	6.0000	0.054	0.025	6.5540	6.5000	6.5000	6.0000	6.7000	0.068	5.8444	0.3966
26	6.5000	5.6292	6.7500	6.701	6.2500	0.054	0.025	6.8040	6.7500	6.7500	6.2500	6.9500	0.068	6.1067	0.3966
27	6.7500	5.8457	7.0000	6.951	6.5000	0.054	0.025	7.0540	7.0000	7.0000	6.5000	7.2000	0.069	6.3458	0.3967
28	7.0000	6.0622	7.2500	7.201	6.7500	0.054	0.025	7.3040	7.2500	7.2500	6.7500	7.4500	0.069	6.6069	0.3967
29	7.2500	6.2787	7.5000	7.451	7.0000	0.054	0.025	7.5540	7.5000	7.5000	7.0000	7.7000	0.069	6.8464	0.3967
30	7.5000	6.4952	7.7500	7.702	7.2500	0.054	0.025	7.8040	7.7500	7.7500	7.2500	7.9500	0.070	7.1069	0.3967
31	7.7500	6.7117	8.0000	7.950	7.5000	0.054	0.026	8.0540	8.0000	8.0000	7.5000	8.2000	0.070	7.3470	0.3967
32	8.0000	6.9282	8.2500	8.200	7.7500	0.055	0.026	8.3040	8.2500	8.2500	7.7500	8.4500	0.070	7.6069	0.3967
33	8.2500	7.1447	8.5000	8.450	8.0000	0.055	0.026	8.5540	8.5000	8.5000	8.0000	8.7000	0.071	7.8476	0.3967
34	8.5000	7.3612	8.7500	8.700	8.2500	0.055	0.026	8.8040	8.7500	8.7500	8.2500	8.9500	0 071	8.1069	0.3967
35	8.7500	7.5777	9.0000	8.950	8.5000	0.055	0.026	9.0540	9.0000	9.0000	8.5000	9.2000	0.071	8.3481	0.3967
36	9.0000	7.7942	9.2500	9.200	8.7500	0.055	0.026	9.3040	9.2500	9.2500	8.7500	9.4500	0.071	8.6069	0.3967
37	9.2500	8.0107	9.5000	9.450	9.0000	0.055	0.026	9.5540	9.5000	9.5000	9.0000	9.7000	0.071	8.8488	0.3968
38	9.5000	8.2273	9.7500	9.700	9.2500	0.055	0.026	9.8040	9.7500	9.7500	9.2500	9.9500	0.072	9.1071	0.3968
39	9.7500	8.4438	10.0000	9.950	9.5000	0.055	0.026	10.0540	10.0000	10.0000	9.5000	10.2000	0.072	9.3493	0.3968
40	10.0000	8.6603	10.2500	10.200	9.7500	0.055	0.026	10.3040	10.2500	10.2500	9.7500	10.4500	0.072	9.6071	0.3968
41	10.2500	8.8768	10.5000	10.450	10.0000	0.055	0.026	10.5540	10.5000	10.5000	10.0000	10.7000	0.072	9.8497	0.3968
42	10.5000	9.0933	10.7500	10.700	10.2500	0.055	0.026	10.8040	10.7500	10.7500	10.2500	10.9500	0.072	10.1071	0.3968
43	10.7500	9.3098	11.0000	10.950	10.5000	0.055	0.026	11.0540	11.0000	11.0000	10.5000	11.2000	0.072	10.3500	0.3968
44	11.0000	9.5263	11.2500	11.198	10.7500	0.056	0.027	11.3040	11.2500	11.2500	10.7500	11.4500	0.072	10.6072	0.3968
45	11.2500	9.7428	11.5000	11.448	11.0000	0.056	0.027	11.5540	11.5000	11.5000	11.0000	11.7000	0.072	10.8503	0.3968
46	11.5000	9.9593	11.7500	11.698	11.2500	0.056	0.027	11.8040	11.7500	11.7500	11.2500	11.9500	0.072	11.1072	0.3968
47	11.7500	10.1758	12.0000	11.948	11.5000	0.056	0.027	12.0540	12.0000	12.0000	11.5000	12.2000	0.072	11.3507	0.3969
48	12.0000	10.3923	12.2500	12.198	11.7500	0.056	0.027	12.3040	12.2500	12.2500	11.7500	12.4500	0.072	11.6073	0.3969
49	12.2500	10.6088	12.5000	12.448	12.0000	0.056	0.027	12.5540	12.5000	12.5000	12.0000	12.7000	0.072	11.8510	0.3969
50	12.5000	10.8253	12.7500	12.698	12.2500	0.056	0.027	12.8040	12.7500	12.7500	12.2500	12.9500	0.072	12.1073	0.3969

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 8b—*4/8 Diametral Pitch, External*[a]

4/8 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.1250 Dedendum (See Sec 6)	Circular Pitch, 0.7854 Meas-Pin Diam, 0.4800

EXTERNAL

N	Major-diameter fit[b]								Fillet root[c]			Dimensions for all fits						
	Major diameter			Major-diam chamfer		Flat-root side fit									Tooth thickness			
						Minor diam	Minor-diam fillet		Major diam	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.3922	0.3942	0.3963
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J^d)	+0.0000 −(0.0006 + J^d)	+0.0009 + J^e −0.0000	App	Min	+0.0000 −0.0300	App	Max	+0.0000 −0.0100	+0.0000 −0.0300	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	1.7485	1.7499	1.7510	0.057	0.023	1.1960	0.043	0.042	1.7500	1.0500	—	1.3091	2.2109	2.2142	2.2169	0.3884	0.3909	0.3930
7	1.9985	1.9999	2.0010	0.057	0.023	1.4460	0.038	0.038	2.0000	1.3000	—	1.5256	2.4148	2.4180	2.4208	0.3883	0.3908	0.3929
8	2.2485	2.2499	2.2510	0.057	0.024	1.6960	0.035	0.034	2.2500	1.5500	0.100	1.7700	2.7176	2.7210	2.7239	0.3883	0.3908	0.3929
9	2.4985	2.4999	2.5011	0.058	0.024	1.9460	0.033	0.032	2.5000	1.8000	0.093	2.0000	2.9324	2.9358	2.9387	0.3883	0.3908	0.3929
10	2.7485	2.7499	2.7511	0.058	0.024	2.1960	0.030	0.030	2.7500	2.0500	0.091	2.2500	3.2224	3.2259	3.2289	0.3883	0.3908	0.3929
11	2.9985	2.9999	3.0011	0.058	0.025	2.4460	0.029	0.028	3.0000	2.3000	0.090	2.5000	3.4439	3.4474	3.4504	0.3883	0.3908	0.3929
12	3.2485	3.2499	3.2511	0.058	0.025	2.6960	0.028	0.027	3.2500	2.5500	0.089	2.7500	3.7261	3.7297	3.7327	0.3883	0.3908	0.3929
13	3.4985	3.4999	3.5012	0.059	0.025	2.9460	0.027	0.026	3.5000	2.8000	0.088	3.0000	3.9521	3.9557	3.9587	0.3883	0.3908	0.3929
14	3.7485	3.7499	3.7512	0.059	0.025	3.1960	0.026	0.025	3.7500	3.0500	0.087	3.2500	4.2288	4.2325	4.2356	0.3883	0.3908	9.3929
15	3.9985	3.9999	4.0012	0.059	0.025	3.4460	0.026	0.024	4.0000	3.3000	0.086	3.5000	4.4581	4.4618	4.4649	0.3883	0.3908	0.3929
16	4.2485	4.2499	4.2512	0.059	0.025	3.6960	0.025	0.023	4.2500	3.5500	0.085	3.7500	4.7311	4.7349	4.7380	0.3883	0.3908	0.3929
17	4.4985	4.4999	4.5013	0.059	0.026	3.9460	0.025	0.023	4.5000	3.8000	0.085	4.0000	4.9629	4.9667	4.9698	0.3883	0.3908	0.3929
18	4.7485	4.7499	4.7513	0.059	0.026	4.1960	0.025	0.022	4.7500	4.0500	0.084	4.2500	5.2330	5.2367	5.2399	0.3883	0.3908	0.3929
19	4.9985	4.9999	5.0013	0.059	0.026	4.4460	0.025	0.022	5.0000	4.3000	0.084	4.5000	5.4667	5.4705	5.4737	0.3883	0.3908	0.3929
20	5.2485	5.2499	5.2513	0.059	0.026	4.6960	0.025	0.021	5.2500	4.5500	0.083	4.7500	5.7345	5.7383	5.7415	0.3883	0.3908	0.3939
21	5.4985	5.4999	5.5014	0.059	0.026	4.9460	0.025	0.021	5.5000	4.8000	0.083	5.0000	5.9697	5.9735	5.9768	0.3882	0.3907	0.3928
22	5.7485	5.7499	5.7514	0.059	0.026	5.1960	0.025	0.021	5.7500	5.0500	0.083	5.2500	6.2357	6.2395	6.2428	0.3882	0.3907	0.3928
23	5.9985	5.9999	6.0014	0.060	0.026	5.4460	0.025	0.020	6.0000	5.3000	0.082	5.5000	6.4723	6.4761	6.4794	0.3882	0.3907	0.3928
24	6.2485	6.2499	6.2514	0.060	0.026	5.6960	0.025	0.020	6.2500	5.5500	0.082	5.7500	6.7368	6.7407	6.7440	0.3882	0.3907	0.3928
25	6.4985	6.4999	6.5015	0.060	0.026	5.9460	0.025	0.020	6.5000	5.8000	0.082	6.0000	6.9745	6.9784	6.9817	0.3882	0.3907	0.3928
26	6.7485	6.7499	6.7515	0.060	0.026	6.1960	0.025	0.019	6.7500	6.0500	0.081	6.2500	7.2378	7.2417	7.2450	0.3882	0.3907	0.3928
27	6.9985	6.9999	7.0015	0.060	0.026	6.4460	0.025	0.019	7.0000	6.3000	0.081	6.5000	7.4764	7.4803	7.4836	0.3882	0.3907	0.3928
28	7.2485	7.2499	7.2515	0.060	0.026	6.6960	0.025	0.019	7.2500	6.5500	0.081	6.7500	7.7386	7.7426	7.7459	0.3882	0.3907	0.3928
29	7.4985	7.4999	7.5016	0.060	0.026	6.9460	0.025	0.019	7.5000	6.8000	0.081	7.0000	7.9780	7.9820	7.9853	0.3882	0.3907	0.3928
30	7.7485	7.7499	7.7516	0.060	0.026	7.1960	0.025	0.019	7.7500	7.0500	0.081	7.2500	8.2395	8.2434	8.2468	0.3882	0.3907	0.3928
31	7.9985	7.9999	8.0016	0.060	0.026	7.4460	0.025	0.018	8.0000	7.3000	0.080	7.5000	8.4795	8.4834	8.4868	0.3882	0.3907	0.3928
32	8.2485	8.2499	8.2516	0.060	0.027	7.6960	0.025	0.018	8.2500	7.5500	0.080	7.7500	8.7402	8.7441	8.7475	0.3882	0.3907	0.3928
33	8.4985	8.4999	8.5017	0.060	0.027	7.9460	0.025	0.018	8.5000	7.8000	0.080	8.0000	8.9808	8.9847	8.9881	0.3882	0.3907	0.3928
34	8.7485	8.7499	8.7517	0.060	0.027	8.1960	0.025	0.018	8.7500	8.0500	0.080	8.2500	9.2407	9.2447	9.2481	0.3882	0.3907	0.3928
35	8.9985	8.9999	9.0017	0.060	0.027	8.4460	0.025	0.018	9.0000	8.3000	0.080	8.5000	9.4818	9.4857	9.4891	0.3881	0.3906	0.3927
36	9.2485	9.2499	9.2517	0.060	0.027	8.6960	0.025	0.018	9.2500	8.5500	0.080	8.7500	9.7411	9.7451	9.7485	0.3881	0.3906	0.3927
37	9.4985	9.4999	9.5018	0.060	0.027	8.9460	0.025	0.018	9.5000	8.8000	0.080	9.0000	9.9828	9.9868	9.9902	0.3881	0.3906	0.3927
38	9.7485	9.7499	9.7518	0.060	0.027	9.1960	0.025	0.018	9.7500	9.0500	0.080	9.2500	10.2416	10.2456	10.2490	0.3881	0.3906	0.3927
39	9.9985	9.9999	10.0018	0.060	0.027	9.4460	0.025	0.017	10.0000	9.3000	0.079	9.5000	10.4837	10.4877	10.4911	0.3881	0.3906	0.3927
40	10.2485	10.2499	10.2518	0.060	0.027	9.6960	0.025	0.017	10.2500	9.5500	0.079	9.7500	10.7421	10.7461	10.7495	0.3881	0.3906	0.3927
41	10.4985	10.4999	10.5019	0.060	0.027	9.9460	0.025	0.017	10.5000	9.8000	0.079	10.0000	10.9846	10.9886	10.9920	0.3881	0.3906	0.3927
42	10.7485	10.7499	10.7519	0.060	0.027	10.1960	0.025	0.017	10.7500	10.0500	0.079	10.2500	11.2425	11.2465	11.2499	0.3881	0.3906	0.3927
43	10.9985	10.9999	11.0019	0.060	0.027	10.4460	0.025	0.017	11.0000	10.3000	0.079	10.5000	11.4854	11.4894	11.4928	0.3881	0.3906	0.3927
44	11.2485	11.2499	11.2519	0.060	0.027	10.6960	0.025	0.017	11.2500	10.5500	0.079	10.7500	11.7428	11.7469	11.7503	0.3881	0.3906	0.3927
45	11.4985	11.4999	11.5020	0.060	0.027	10.9460	0.025	0.017	11.5000	10.8000	0.079	11.0000	11.9860	11.9901	11.9935	0.3881	0.3906	0.3927
46	11.7485	11.7499	11.7520	0.060	0.027	11.1960	0.025	0.017	11.7500	11.0500	0.079	11.2500	12.2432	12.2473	12.2507	0.3881	0.3906	0.3927
47	11.9985	11.9999	12.0020	0.060	0.027	11.4460	0.025	0.017	12.0000	11.3000	0.079	11.5000	12.4867	12.4908	12.4942	0.3881	0.3906	0.3927
48	12.2485	12.2499	12.2520	0.060	0.027	11.6960	0.025	0.017	12.2500	11.5500	0.078	11.7500	12.7435	12.7476	12.7510	0.3881	0.3906	0.3927
49	12.4985	12.4999	12.5021	0.060	0.027	11.9460	0.025	0.017	12.5000	11.8000	0.078	12.0000	12.9871	12.9912	12.9946	0.3880	0.3905	0.3926
50	12.7485	12.7499	12.7521	0.060	0.027	12.1960	0.025	0.017	12.7500	12.0500	0.078	12.2500	13.2437	13.2478	13.2512	0.3880	0.3905	0.3926

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 8a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27) except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 9a—*5/10 Diametral Pitch, Internal*[a]

5/10 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.1000 Dedendum (See Sec 6)	Circular Pitch, 0.6283 Meas-Pin Diam, 0.2880

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits	
					Flat-Root Side Fit										
						Major-diam fillet		Major diam							
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad	Measurement between pins	Space width: Min effective 0.3142
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance⟶			$+0.0007 + L^d$ -0.0000	Min	$+0.0035$ -0.0000	App	Max	$+0.0250$ -0.0000	$+0.0007 + L^d$ $-(0.0007 + L)$	Min	$+0.0035$ -0.0000	$+0.0250$ -0.0000	Min[e]	Max	Dimensional Max[f]
6	1.2000	1.0392	1.4000	1.381	1.0492	0.029	0.010	1.4440	1.4000	1.4000	1.0492	1.5600	0.030	0.8859	0.3180
7	1.4000	1.2124	1.6000	1.577	1.2224	0.032	0.012	1.6440	1.6000	1.6000	1.2224	1.7600	0.036	1.0505	0.3180
8	1.6000	1.3856	1.8000	1.775	1.4200	0.034	0.013	1.8440	1.8000	1.8000	1.4200	1.9600	0.038	1.2861	0.3180
9	1.8000	1.5588	2.0000	1.973	1.6000	0.036	0.014	2.0440	2.0000	2.0000	1.6000	2.1600	0.041	1.4593	0.3180
10	2.0000	1.7321	2.2000	2.171	1.8000	0.037	0.015	2.2440	2.2000	2.2000	1.8000	2.3600	0.043	1.6862	0.3180
11	2.2000	1.9053	2.4000	2.369	2.0000	0.038	0.016	2.4440	2.4000	2.4000	2.0000	2.5600	0.045	1.8641	0.3180
12	2.4000	2.0785	2.6000	2.569	2.2000	0.039	0.016	2.6400	2.6000	2.6000	2.2000	2.7600	0.046	2.0864	0.3180
13	2.6000	2.2517	2.8000	2.767	2.4000	0.039	0.017	2.8440	2.8000	2.8000	2.4000	2.9600	0.048	2.2676	0.3180
14	2.8000	2.4249	3.0000	2.967	2.6000	0.040	0.017	3.0440	3.0000	3.0000	2.6000	3.1600	0.049	2.4864	0.3180
15	3.0000	2.5981	3.2000	3.165	2.8000	0.040	0.018	3.2440	3.2000	3.2000	2.8000	3.3600	0.049	2.6701	0.3180
16	3.2000	2.7713	3.4000	3.365	3.0000	0.041	0.018	3.4440	3.4000	3.4000	3.0000	3.5600	0.050	2.8866	0.3181
17	3.4000	2.9445	3.6000	3.565	3.2000	0.041	0.018	3.6440	3.6000	3.6000	3.2000	3.7600	0.051	3.0722	0.3181
18	3.6000	3.1177	3.8000	3.763	3.4000	0.041	0.019	3.8440	3.8000	3.8000	3.4000	3.9600	0.051	3.2866	0.3181
19	3.8000	3.2909	4.0000	3.963	3.6000	0.042	0.019	4.0440	4.0000	4.0000	3.6000	4.1600	0.052	3.4738	0.3181
20	4.0000	3.4641	4.2000	4.163	3.8000	0.042	0.019	4.2440	4.2000	4.2000	3.8000	4.3600	0.052	3.6866	0.3181
21	4.2000	3.6373	4.4000	4.363	4.0000	0.042	0.019	4.4440	4.4000	4.4000	4.0000	4.5600	0.052	3.8750	0.3181
22	4.4000	3.8105	4.6000	4.563	4.2000	0.042	0.019	4.6440	4.6000	4.6000	4.2000	4.7600	0.053	4.0867	0.3181
23	4.6000	3.9837	4.8000	4.763	4.4000	0.042	0.019	4.8440	4.8000	4.8000	4.4000	4.9600	0.053	4.2760	0.3181
24	4.8000	4.1569	5.0000	4.961	4.6000	0.043	0.020	5.0440	5.0000	5.0000	4.6000	5.1600	0.053	4.4867	0.3181
25	5.0000	4.3301	5.2000	5.161	4.8000	0.043	0.020	5.2440	5.2000	5.2000	4.8000	5.3600	0.054	4.6769	0.3181
26	5.2000	4.5033	5.4000	5.361	5.0000	0.043	0.020	5.4440	5.4000	5.4000	5.0000	5.5600	0.054	4.8867	0.3181
27	5.4000	4.6765	5.6000	5.561	5.2000	0.043	0.020	5.6440	5.6000	5.6000	5.2000	5.7600	0.054	5.0778	0.3182
28	5.6000	4.8497	5.8000	5.761	5.4000	0.043	0.020	5.8440	5.8000	5.8000	5.4000	5.9600	0.054	5.2870	0.3182
29	5.8000	5.0229	6.0000	5.961	5.6000	0.043	0.020	6.0440	6.0000	6.0000	5.6000	6.1600	0.054	5.4784	0.3182
30	6.0000	5.1962	6.2000	6.161	5.8000	0.043	0.020	6.2440	6.2000	6.2000	5.8000	6.3600	0.055	5.6869	0.3182
31	6.2000	5.3694	6.4000	6.361	6.0000	0.044	0.020	6.4440	6.4000	6.4000	6.0000	6.5600	0.055	5.8790	0.3182
32	6.4000	5.5426	6.6000	6.559	6.2000	0.044	0.021	6.6440	6.6000	6.6000	6.2000	6.7600	0.055	6.0869	0.3182
33	6.6000	5.7158	6.8000	6.759	6.4000	0.044	0.021	6.8440	6.8000	6.8000	6.4000	6.9600	0.055	6.2795	0.3182
34	6.8000	5.8890	7.0000	6.959	6.6000	0.044	0.021	7.0440	7.0000	7.0000	6.6000	7.1600	0.055	6.4869	0.3182
35	7.0000	6.0622	7.2000	7.159	6.8000	0.044	0.021	7.2440	7.2000	7.2000	6.8000	7.3600	0.055	6.6799	0.3182
36	7.2000	6.2354	7.4000	7.359	7.0000	0.044	0.021	7.4440	7.4000	7.4000	7.0000	7.5600	0.055	6.8869	0.3182
37	7.4000	6.4086	7.6000	7.559	7.2000	0.044	0.021	7.6440	7.6000	7.6000	7.2000	7.7600	0.055	7.0805	0.3183
38	7.6000	6.5818	7.8000	7.759	7.4000	0.044	0.021	7.8440	7.8000	7.8000	7.4000	7.9600	0.056	7.2871	0.3183
39	7.8000	6.7550	8.0000	7.960	7.6000	0.044	0.021	8.0440	8.0000	8.0000	7.6000	8.1600	0.056	7.4808	0.3183
40	8.0000	6.9282	8.2000	8.160	7.8000	0.044	0.021	8.2440	8.2000	8.2000	7.8000	8.3600	0.056	7.6871	0.3183
41	8.2000	7.1014	8.4000	8.360	8.0000	0.044	0.021	8.4440	8.4000	8.4000	8.0000	8.5600	0.056	7.8812	0.3183
42	8.4000	7.2746	8.6000	8.560	8.2000	0.044	0.021	8.6440	8.6000	8.6000	8.2000	8.7600	0.056	8.0871	0.3183
43	8.6000	7.4478	8.8000	8.760	8.4000	0.044	0.021	8.8440	8.8000	8.8000	8.4000	8.9600	0.056	8.2814	0.3183
44	8.8000	7.6210	9.0000	8.960	8.6000	0.044	0.021	9.0440	9.0000	9.0000	8.6000	9.1600	0.056	8.4872	0.3183
45	9.0000	7.7942	9.2000	9.160	8.8000	0.044	0.021	9.2440	9.2000	9.2000	8.8000	9.3600	0.056	8.6817	0.3183
46	9.2000	7.9674	9.4000	9.360	9.0000	0.044	0.021	9.4440	9.4000	9.4000	9.0000	9.5600	0.056	8.8872	0.3183
47	9.4000	8.1406	9.6000	9.560	9.2000	0.045	0.021	9.6440	9.6000	9.6000	9.2000	9.7600	0.056	9.0820	0.3184
48	9.6000	8.3138	9.8000	9.760	9.4000	0.045	0.021	9.8440	9.8000	9.8000	9.4000	9.9600	0.056	9.2873	0.3184
49	9.8000	8.4870	10.0000	9.960	9.6000	0.045	0.021	10.0440	10.0000	10.0000	9.6000	10.1600	0.056	9.4823	0.3184
50	10.0000	8.6603	10.2000	10.160	9.8000	0.045	0.021	10.2440	10.2000	10.2000	9.8000	10.3600	0.056	9.6873	0.3184

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] $L = 0.0001 \times$ diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 9b—*5/10 Diametral Pitch, External*[a]

5/10 Diametral Pitch
Pressure Angle, 30°

Addendum (Basic), 0.1000
Dedendum (See Sec 6)

Circular Pitch, 0.6283
Meas-Pin Diam, 0.3840

EXTERNAL

N	Major-diameter fit[b]																	
	Major diameter			Major-diam chamfer		Flat-root side fit			Fillet root[c]			Dimensions for all fits						
						Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Tooth thickness		
																Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.3137	0.3157	0.3178
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J^e)	+0.0000 −(0.0006 + J^e)	+0.0009 + J^e −0.0000	App	Min	+0.0000 −0.0250	App	Max	+0.0000 −0.0070	+0.0000 −0.0250	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	1.3985	1.3999	1.4009	0.046	0.018	0.9560	0.034	0.034	1.4000	0.8400	—	1.0492	1.7676	1.7709	1.7736	0.3099	0.3124	0.3145
7	1.5985	1.5999	1.6010	0.046	0.019	1.1560	0.030	0.030	1.6000	1.0400	—	1.2224	1.9307	1.9339	1.9367	0.3098	0.3123	0.3144
8	1.7985	1.7999	1.8010	0.046	0.019	1.3560	0.028	0.027	1.8000	1.2400	0.078	1.4200	2.1729	2.1763	2.1792	0.3098	0.3123	0.3144
9	1.9985	1.9999	2.0010	0.046	0.019	1.5560	0.026	0.025	2.0000	1.4400	0.074	1.6000	2.3447	2.3481	2.3510	0.3098	0.3123	0.3144
10	2.1985	2.1999	2.2010	0.047	0.020	1.7560	0.024	0.024	2.2000	1.6400	0.073	1.8000	2.5767	2.5802	2.5832	0.3098	0.3123	0.3144
11	2.3985	2.3999	2.4010	0.047	0.020	1.9560	0.023	0.023	2.4000	1.8400	0.072	2.0000	2.7539	2.7574	2.7604	0.3098	0.3123	0.3144
12	2.5985	2.5999	2.6011	0.047	0.020	2.1560	0.022	0.021	2.6000	2.0400	0.071	2.2000	2.9796	2.9832	2.9862	0.3098	0.3123	0.3144
13	2.7985	2.7999	2.8011	0.047	0.020	2.3560	0.022	0.021	2.8000	2.2400	0.070	2.4000	3.1604	3.1640	3.1670	0.3098	0.3123	0.3144
14	2.9985	2.9999	3.0011	0.047	0.020	2.5560	0.021	0.020	3.0000	2.4400	0.069	2.6000	3.3817	3.3854	3.3885	0.3098	0.3123	0.3144
15	3.1985	3.1999	3.2011	0.047	0.020	2.7560	0.020	0.019	3.2000	2.6400	0.069	2.8000	3.5652	3.5689	3.5720	0.3098	0.3123	0.3144
16	3.3985	3.3999	3.4011	0.047	0.020	2.9560	0.020	0.019	3.4000	2.8400	0.068	3.0000	3.7835	3.7873	3.7904	0.3098	0.3123	0.3144
17	3.5985	3.5999	3.6012	0.047	0.021	3.1560	0.020	0.018	3.6000	3.0400	0.068	3.2000	3.9690	3.9728	3.9759	0.3098	0.3123	0.3144
18	3.7985	3.7999	3.8012	0.047	0.021	3.3560	0.020	0.018	3.8000	3.2400	0.067	3.4000	4.1851	4.1888	4.1920	0.3098	0.3123	0.3144
19	3.9985	3.9999	4.0012	0.047	0.021	3.5560	0.020	0.017	4.0000	3.4400	0.067	3.6000	4.3720	4.3758	4.3790	0.3098	0.3123	0.3144
20	4.1985	4.1999	4.2012	0.047	0.021	3.7560	0.020	0.017	4.2000	3.6400	0.066	3.8000	4.5863	4.5901	4.5933	0.3098	0.3123	0.3144
21	4.3985	4.3999	4.4012	0.047	0.021	3.9560	0.020	0.017	4.4000	3.8400	0.066	4.0000	4.7742	4.7781	4.7814	0.3097	0.3122	0.3143
22	4.5985	4.5999	4.6013	0.047	0.021	4.1560	0.020	0.016	4.6000	4.0400	0.066	4.2000	4.9872	4.9910	4.9943	0.3097	0.3122	0.3143
23	4.7985	4.7999	4.8013	0.048	0.021	4.3560	0.020	0.016	4.8000	4.2400	0.066	4.4000	5.1765	5.1803	5.1836	0.3097	0.3122	0.3143
24	4.9985	4.9999	5.0013	0.048	0.021	4.5560	0.020	0.016	5.0000	4.4400	0.065	4.6000	5.3880	5.3919	5.3952	0.3097	0.3122	0.3143
25	5.1985	5.1999	5.2013	0.048	0.021	4.7560	0.020	0.016	5.2000	4.6400	0.065	4.8000	5.5782	5.5821	5.5854	0.3097	0.3122	0.3143
26	5.3985	5.3999	5.4013	0.048	0.021	4.9560	0.020	0.016	5.4000	4.8400	0.065	5.0000	5.7889	5.7928	5.7961	0.3097	0.3122	0.3143
27	5.5985	5.5999	5.6014	0.048	0.021	5.1560	0.020	0.015	5.6000	5.0400	0.065	5.2000	5.9797	5.9836	5.9869	0.3097	0.3122	0.3143
28	5.7985	5.7999	5.8014	0.048	0.021	5.3560	0.020	0.015	5.8000	5.2400	0.065	5.4000	6.1895	6.1935	6.1968	0.3097	0.3122	0.3143
29	5.9985	5.9999	6.0014	0.048	0.021	5.5560	0.020	0.015	6.0000	5.4400	0.064	5.6000	6.3810	6.3850	6.3883	0.3097	0.3122	0.3143
30	6.1985	6.1999	6.2014	0.048	0.021	5.7560	0.020	0.015	6.2000	5.6400	0.064	5.8000	6.5901	6.5940	6.5974	0.3097	0.3122	0.3143
31	6.3985	6.3999	6.4014	0.048	0.021	5.9560	0.020	0.015	6.4000	5.8400	0.064	6.0000	6.7822	6.7861	6.7895	0.3097	0.3122	0.3143
32	6.5985	6.5999	6.6015	0.048	0.021	6.1560	0.020	0.015	6.6000	6.0400	0.064	6.2000	6.9907	6.9946	6.9980	0.3097	0.3122	0.3143
33	6.7985	6.7999	6.8015	0.048	0.021	6.3560	0.020	0.014	6.8000	6.2400	0.064	6.4000	7.1832	7.1871	7.1905	0.3097	0.3122	0.3143
34	6.9985	6.9999	7.0015	0.048	0.021	6.5560	0.020	0.014	7.0000	6.4400	0.064	6.6000	7.3911	7.3951	7.3985	0.0397	0.3122	0.3143
35	7.1985	7.1999	7.2015	0.048	0.021	6.7560	0.020	0.014	7.2000	6.6400	0.064	6.8000	7.5840	7.5879	7.5913	0.0396	0.3121	0.3142
36	7.3985	7.3999	7.4015	0.048	0.021	6.9560	0.020	0.014	7.4000	6.8400	0.064	7.0000	7.7914	7.7954	7.7988	0.3096	0.3121	0.3142
37	7.5985	7.5999	7.6016	0.048	0.021	7.1560	0.020	0.014	7.6000	7.0400	0.063	7.2000	7.9847	7.9887	7.9921	0.3096	0.3121	0.3142
38	7.7985	7.7999	7.8016	0.048	0.021	7.3560	0.020	0.014	7.8000	7.2400	0.063	7.4000	8.1918	8.1958	8.1992	0.3096	0.3121	0.3142
39	7.9985	7.9999	8.0016	0.048	0.021	7.5560	0.020	0.014	8.0000	7.4400	0.063	7.6000	8.3855	8.3885	8.3929	0.3096	0.3121	0.3142
40	8.1985	8.1999	8.2016	0.048	0.021	7.7560	0.020	0.014	8.2000	7.6400	0.063	7.8000	8.5922	8.5962	8.5996	0.3096	0.3121	0.3142
41	8.3985	8.3999	8.4016	0.048	0.021	7.9560	0.020	0.014	8.4000	7.8400	0.063	8.0000	8.7862	8.7902	8.7936	0.3096	0.3121	0.3142
42	8.5985	8.5999	8.6017	0.048	0.021	8.1560	0.020	0.014	8.6000	8.0400	0.063	8.2000	8.9925	8.9965	8.9999	0.3096	0.3121	0.3142
43	8.7985	8.7999	8.8017	0.048	0.021	8.3560	0.020	0.014	8.8000	8.2400	0.063	8.4000	9.1868	9.1908	9.1942	0.3096	0.3121	0.3142
44	8.9985	8.9999	9.0017	0.048	0.021	8.5560	0.020	0.014	9.0000	8.4400	0.063	8.6000	9.3928	9.3969	9.4003	0.3096	0.3121	0.3142
45	9.1985	9.1999	9.2017	0.048	0.021	8.7560	0.020	0.013	9.2000	8.6400	0.063	8.8000	9.5873	9.5914	9.5948	0.3096	0.3121	0.3142
46	9.3985	9.3999	9.4017	0.048	0.021	8.9560	0.020	0.013	9.4000	8.8400	0.063	9.0000	9.7931	9.7972	9.8006	0.3096	0.3121	0.3142
47	9.5985	9.5999	9.6018	0.048	0.021	9.1560	0.020	0.013	9.6000	9.0400	0.062	9.2000	9.9878	9.9919	9.9953	0.3096	0.3121	0.3142
48	9.7985	9.7999	9.8018	0.048	0.021	9.3560	0.020	0.013	9.8000	9.2400	0.062	9.4000	10.1933	10.1974	10.2008	0.3096	0.3121	0.3142
49	9.9985	9.9999	10.0018	0.048	0.021	9.5560	0.020	0.013	10.0000	9.4400	0.062	9.6000	10.3881	10.3922	10.3956	0.3095	0.3120	0.3141
50	10.1985	10.1999	10.2018	0.048	0.021	9.7560	0.020	0.013	10.2000	9.6400	0.062	9.8000	10.5934	10.5975	10.6009	0.3095	0.3120	0.3141

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 9a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 10a—*6/12 Diametral Pitch, Internal*[a]

6/12 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0833 Dedendum (See Sec 6)	Circular Pitch, 0.5236 Meas-Pin Diam, 0.2400

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit				All fits	
					Flat-Root Side Fit										Space width
						Major-diam fillet		Major diam						Measurement between pins	
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad		Min effective 0.2618
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance ⟶			+0.0097 + L^d −0.0000	Min	+0.0035 −0.0000	App	Max	+0.0217 −0.0000	+0.0007 + L^d −(0.0007 + L)	Min	+0.0035 −0.0000	+0.0217 −0.0000	Min[e]	Max	Dimensional Max[f]
6	1.0000	0.8660	1.1667	1.150	0.8760	0.024	0.009	1.2040	1.1667	1.1667	0.8760	1.3000	0.023	0.7379	0.2648
7	1.1667	1.0104	1.3333	1.314	1.0204	0.027	0.010	1.3707	1.3333	1.3333	1.0204	1.4667	0.029	0.8762	0.2649
8	1.3333	1.1547	1.5000	1.479	1.1727	0.028	0.011	1.5373	1.5000	1.5000	1.1727	1.6333	0.032	1.0716	0.2649
9	1.5000	1.2990	1.6667	1.644	1.3333	0.030	0.012	1.7040	1.6667	1.6667	1.3333	1.8000	0.034	1.2159	0.2649
10	1.6667	1.4434	1.8333	1.808	1.5000	0.031	0.013	1.8707	1.8333	1.8333	1.5000	1.9667	0.035	1.4051	0.2649
11	1.8333	1.5877	2.0000	1.975	1.6667	0.032	0.013	2.0373	2.0000	2.0000	1.6667	2.1333	0.037	1.5534	0.2649
12	2.0000	1.7321	2.1667	2.140	1.8333	0.032	0.014	2.2040	2.1667	2.1667	1.8333	2.3000	0.038	1.7385	0.2649
13	2.1667	1.8764	2.3333	2.306	2.0000	0.033	0.014	2.3707	2.3333	2.3333	2.0000	2.4667	0.039	1.8895	0.2649
14	2.3333	2.0207	2.5000	2.473	2.1667	0.033	0.014	2.5373	2.5000	2.5000	2.1667	2.6333	0.040	2.0719	0.2649
15	2.5000	2.1651	2.6667	2.638	2.3333	0.034	0.015	2.7040	2.6667	2.6667	2.3333	2.8000	0.041	2.2250	0.2649
16	2.6667	2.3094	2.8333	2.804	2.5000	0.034	0.015	2.8707	2.8333	2.8333	2.5000	2.9667	0.041	2.4052	0.2649
17	2.8333	2.4537	3.0000	2.971	2.6667	0.034	0.015	3.0373	3.0000	3.0000	2.6667	3.1333	0.042	2.5599	0.2649
18	3.0000	2.5981	3.1667	3.136	2.8333	0.035	0.016	3.2040	3.1667	3.1667	2.8333	3.3000	0.042	2.7386	0.2649
19	3.1667	2.7424	3.3333	3.302	3.0000	0.035	0.016	3.3707	3.3333	3.3333	3.0000	3.4667	0.043	2.8946	0.2649
20	3.3333	2.8868	3.5000	3.469	3.1667	0.035	0.016	3.5373	3.5000	3.5000	3.1667	3.6333	0.043	3.0720	0.2649
21	3.5000	3.0311	3.6667	3.636	3.3333	0.035	0.016	3.7040	3.6667	3.6667	3.3333	3.8000	0.043	3.2291	0.2650
22	3.6667	3.1754	3.8333	3.802	3.5000	0.035	0.016	3.8707	3.8333	3.8333	3.5000	3.9667	0.043	3.4055	0.2650
23	3.8333	3.3198	4.0000	3.969	3.6667	0.035	0.016	4.0373	4.0000	4.0000	3.6667	4.1333	0.044	3.5633	0.2650
24	4.0000	3.4641	4.1667	4.136	3.8333	0.036	0.016	4.2040	4.1667	4.1667	3.8333	4.3000	0.044	3.7389	0.2650
25	4.1667	3.6084	4.3333	4.300	4.0000	0.036	0.017	4.3707	4.3333	4.3333	4.0000	4.4667	0.044	3.8973	0.2650
26	4.3333	3.7528	4.5000	4.467	4.1667	0.036	0.017	4.5373	4.5000	4.5000	4.1667	4.6333	0.044	4.0721	0.2650
27	4.5000	3.8971	4.6667	4.634	4.3333	0.036	0.017	4.7040	4.6667	4.6667	4.3333	4.8000	0.045	4.2312	0.2650
28	4.6667	4.0415	4.8333	4.801	4.5000	0.036	0.017	4.8707	4.8333	4.8333	4.5000	4.9667	0.045	4.4055	0.2650
29	4.8333	4.1858	5.0000	4.967	4.6667	0.036	0.017	5.0373	5.0000	5.0000	4.6667	5.1333	0.045	4.5651	0.2650
30	5.0000	4.3301	5.1667	5.134	4.8333	0.036	0.017	5.2040	5.1667	5.1667	4.8333	5.3000	0.045	4.7388	0.2650
31	5.1667	4.4745	5.3333	5.301	5.0000	0.036	0.017	5.3707	5.3333	5.3333	5.0000	5.4667	0.045	4.8989	0.2650
32	5.3333	4.6188	5.5000	5.467	5.1667	0.036	0.017	5.5373	5.5000	5.5000	5.1667	5.6333	0.045	5.0722	0.2650
33	5.5000	4.7631	5.6667	5.634	5.3333	0.037	0.017	5.7040	5.6667	5.6667	5.3333	5.8000	0.045	5.2327	0.2650
34	5.6667	4.9075	5.8333	5.801	5.5000	0.037	0.017	5.8707	5.8333	5.8333	5.5000	5.9667	0.046	5.4055	0.2650
35	5.8333	5.0518	6.0000	5.967	5.6667	0.037	0.017	6.0373	6.0000	6.0000	5.6667	6.1333	0.046	5.5666	0.2651
36	6.0000	5.1962	6.1667	6.134	5.8333	0.037	0.017	6.2040	6.1667	6.1667	5.8333	6.3000	0.036	5.7391	0.2651
37	6.1667	5.3405	6.3333	6.301	6.0000	0.037	0.017	6.3707	6.3333	6.3333	6.0000	6.4667	0.046	5.9002	0.2651
38	6.3333	5.4848	6.5000	6.465	6.1667	0.037	0.018	6.5373	6.5000	6.5000	6.1667	6.6333	0.046	6.0724	0.2651
39	6.5000	5.6292	6.6667	6.632	6.3333	0.037	0.018	6.7040	6.6667	6.6667	6.3333	6.8000	0.046	6.2338	0.2651
40	6.6667	5.7735	6.8333	6.799	6.5000	0.037	0.018	6.8707	6.8333	6.8333	6.5000	6.9667	0.046	6.4058	0.2651
41	6.8333	5.9178	7.0000	6.965	6.6667	0.037	0.018	7.0373	7.0000	7.0000	6.6667	7.1333	0.046	6.5674	0.2651
42	7.0000	6.0622	7.1667	7.132	6.8333	0.037	0.018	7.2040	7.1667	7.1667	6.8333	7.3000	0.046	6.7391	0.2651
43	7.1667	6.2065	7.3333	7.299	7.0000	0.037	0.018	7.3707	7.3333	7.3333	7.0000	7.4667	0.046	6.9010	0.2651
44	7.3333	6.3509	7.5000	7.466	7.1667	0.037	0.018	7.5373	7.5000	7.5000	7.1667	7.6333	0.046	7.0724	0.2651
45	7.5000	6.4952	7.6667	7.632	7.3333	0.037	0.018	7.7040	7.6667	7.6667	7.3333	7.8000	0.047	7.2346	0.2651
46	7.6667	6.6395	7.8333	7.799	7.5000	0.037	0.018	7.8707	7.8333	7.8333	7.5000	7.9667	0.047	7.4058	0.2651
47	7.8333	6.7839	8.0000	7.966	7.6667	0.037	0.018	8.0373	8.0000	8.0000	7.6667	8.1333	0.047	7.5681	0.2651
48	8.0000	6.9282	8.1667	8.132	7.8333	0.037	0.018	8.2040	8.1667	8.1667	7.8333	8.3000	0.047	7.7391	0.2651
49	8.1667	7.0725	8.3333	8.299	8.0000	0.037	0.018	8.3707	8.3333	8.3333	8.0000	8.4667	0.047	7.9017	0.2652
50	8.3333	7.2169	8.5000	8.466	8.1667	0.037	0.018	8.5373	8.5000	8.5000	8.1667	8.6333	0.047	8.0726	0.2652

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 10b—*6/12 Diametral Pitch, External*[a]

6/12 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0833 Dedendum (See Sec 6)	Circular Pitch, 0.5236 Meas-Pin Diam, 0.3200

EXTERNAL

N	Major-diameter fit[b]									Fillet root[c]		Dimensions for all fits							
	Major diameter			Major-diam chamfer		Flat-root side fit			Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Tooth thickness		
						Minor diam	Minor-diam fillet									Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	C III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.2613	0.2631	0.2648
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0090 −(0.0019 + J^e)	+0.0060 −(0.0006 + J^e)	+0.0009 + J^e −0.0000	App	Min	+0.0000 −0.0217	App	Max	+0.0000 −0.0070	+0.0000 −0.9217	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	1.1652	1.1666	1.1676	0.038	0.015	0.7960	0.028	0.028	1.1667	0.7000	—	0.8670	1.4730	1.4754	1.4776	0.2582	0.2600	0.2617
7	1.3318	1.3332	1.3342	0.038	0.016	0.9627	0.025	0.025	1.3333	0.8667	—	1.0204	1.6090	1.6114	1.6136	0.2582	0.2600	0.2617
8	1.4985	1.4999	1.5010	0.038	0.016	1.1293	0.023	0.023	1.5000	1.0333	0.065	1.1727	1.8108	1.8132	1.8156	0.2582	0.2600	0.2617
9	1.6652	1.6666	1.6677	0.039	0.016	1.2960	0.022	0.021	1.6667	1.2000	0.062	1.3333	1.9540	1.9564	1.9588	0.2582	0.2600	0.2617
10	1.8318	1.8332	1.8343	0.039	0.016	1.4627	0.020	0.020	1.8333	1.3667	0.061	1.5000	2.1472	2.1497	2.1521	0.2581	0.2599	0.2616
11	1.9985	1.9999	2.0010	0.039	0.017	1.6293	0.019	0.019	2.0000	1.5333	0.060	1.6667	2.2949	2.2974	2.2998	0.2581	0.2599	0.2616
12	2.1652	2.1666	2.1677	0.039	0.017	1.7960	0.018	0.018	2.1667	1.7000	0.059	1.8333	2.4830	2.4856	2.4880	0.2581	0.2599	0.2616
13	2.3318	2.3332	2.3343	0.039	0.017	1.9627	0.018	0.017	2.3333	1.8667	0.058	2.0000	2.6336	2.6362	2.6386	0.2581	0.2599	0.2616
14	2.4985	2.4999	2.5011	0.039	0.017	2.1293	0.018	0.017	2.5000	2.0333	0.058	2.1667	2.8181	2.8207	2.8232	0.2581	0.2599	0.2616
15	2.6652	2.6666	2.6678	0.039	0.017	2.2960	0.017	0.016	2.6667	2.2000	0.057	2.3333	2.9710	2.9736	2.9761	0.2581	0.2599	0.2616
16	2.8318	2.8332	2.8344	0.039	0.017	2.4627	0.017	0.016	2.8333	2.3667	0.057	2.5000	3.1530	3.1557	3.1582	0.2581	0.2599	0.2616
17	2.9985	2.9999	3.0011	0.039	0.017	2.6293	0.017	0.015	3.0000	2.5333	0.056	2.6667	3.3075	3.3102	3.3127	0.2581	0.2599	0.2616
18	3.1652	3.1666	3.1678	0.040	0.017	2.7960	0.017	0.015	3.1667	2.7000	0.056	2.8333	3.4875	3.4902	3.4928	0.2581	0.2599	0.2616
19	3.3318	3.3332	3.3344	0.040	0.017	2.9627	0.017	0.015	3.3333	2.8667	0.055	3.0000	3.6433	3.6460	3.6486	0.2581	0.2599	0.2616
20	3.4985	3.4999	3.5012	0.040	0.017	3.1293	0.017	0.014	3.5000	3.0333	0.055	3.1667	3.8219	3.8246	3.8272	0.2581	0.2599	0.2616
21	3.6652	3.6666	3.6679	0.040	0.017	3.2960	0.017	0.014	3.6667	3.2000	0.055	3.3333	3.9788	3.9815	3.9841	0.2581	0.2599	0.2616
22	3.8318	3.8332	3.8345	0.040	0.017	3.4627	0.017	0.014	3.8333	3.6667	0.055	3.5000	4.1560	4.1588	4.1614	0.2581	0.2599	0.2616
23	3.9985	3.9999	4.0012	0.040	0.017	3.6293	0.017	0.014	4.0000	3.5333	0.054	3.6667	4.3138	4.3166	4.3192	0.2581	0.2599	0.2616
24	4.1652	4.1666	4.1679	0.040	0.018	3.7960	0.017	0.013	4.1667	3.7000	0.054	3.8333	4.4902	4.4930	4.4956	0.2581	0.2599	0.2616
25	4.3318	4.3332	4.3345	0.040	0.018	3.9627	0.017	0.013	4.3333	3.8667	0.054	4.0000	4.6486	4.6514	4.6540	0.2581	0.2599	0.2616
26	4.4985	4.4999	4.5013	0.040	0.018	4.1293	0.017	0.013	4.5000	4.0333	0.054	4.1667	4.8241	4.8269	4.8296	0.2581	0.2599	0.2616
27	4.6652	4.6666	4.6680	0.040	0.018	4.2960	0.017	0.013	4.6667	4.2000	0.054	4.3333	4.9832	4.9860	4.9887	0.2581	0.2599	0.2616
28	4.8318	4.8332	4.8346	0.040	0.018	4.4627	0.017	0.013	4.8333	4.3667	0.053	4.5000	5.1578	5.1607	5.1633	0.2580	0.2598	0.2615
29	4.9985	4.9999	5.0013	0.040	0.018	4.6293	0.017	0.013	5.0000	4.5333	0.053	4.6667	5.3174	5.3203	5.3229	0.2580	0.2598	0.2615
30	5.1652	5.1666	5.1680	0.040	0.018	4.7960	0.017	0.012	5.1667	4.7000	0.053	4.8333	5.4917	5.4945	5.4972	0.2580	0.2598	0.2615
31	5.3318	5.3332	5.3346	0.040	0.018	4.9627	0.017	0.012	5.3333	4.8667	0.053	5.0000	5.6518	5.6546	5.6573	0.2580	0.2598	0.2615
32	5.4985	5.4999	5.5014	0.040	0.018	5.1293	0.017	0.012	5.5000	5.0333	0.053	5.1667	5.8255	5.8283	5.8310	0.2580	0.2598	0.2615
33	5.6652	5.6666	5.6681	0.040	0.018	5.2960	0.017	0.012	5.6667	5.2000	0.053	5.3333	5.9860	5.9888	5.9915	0.2580	0.2598	0.2615
34	5.8318	5.8332	5.8347	0.040	0.018	5.4627	0.017	0.012	5.8333	5.3667	0.053	5.5000	6.1592	6.1621	6.1648	0.2580	0.2598	0.2615
35	5.9985	5.9999	6.0014	0.040	0.018	5.6293	0.017	0.012	6.0000	5.5333	0.053	5.6667	6.3200	6.3229	6.3256	0.2580	0.2598	0.2615
36	6.1652	6.1666	6.1681	0.040	0.018	5.7960	0.017	0.012	6.1667	5.7000	0.053	5.8333	6.4929	6.4958	6.4985	0.2580	0.2598	0.2615
37	6.3318	6.3332	6.3347	0.040	0.018	5.9627	0.017	0.012	6.3333	5.8667	0.053	6.0000	6.6540	6.6569	6.6596	0.2580	0.2598	0.2615
38	6.4985	6.4999	6.5015	0.040	0.018	6.1293	0.017	0.012	6.5000	6.0333	0.052	6.1667	6.8266	6.8295	6.8322	0.2580	0.2598	0.2615
39	6.6652	6.6666	6.6682	0.040	0.018	6.2960	0.017	0.012	6.6667	6.2000	0.052	6.3333	6.9880	6.9909	6.9936	0.2580	0.2598	0.2615
40	6.8318	6.8332	6.8348	0.040	0.018	6.4627	0.017	0.012	6.8333	6.3667	0.052	6.5000	7.1602	7.1631	7.1658	0.2580	0.2598	0.2615
41	6.9985	6.9999	7.0015	0.040	0.018	6.6293	0.017	0.012	7.0000	6.5333	0.052	6.6667	7.3219	7.3248	7.3275	0.2580	0.2598	0.2615
42	7.1652	7.1666	7.1682	0.040	0.018	6.7960	0.017	0.011	7.1667	6.7000	0.052	6.8333	7.4938	7.4967	7.4994	0.2580	0.2598	0.2615
43	7.3318	7.3332	7.3348	0.040	0.018	6.9627	0.017	0.011	7.3333	6.8667	0.052	7.0000	7.6558	7.6587	7.6614	0.2580	0.2598	0.2615
44	7.4985	7.4999	7.5016	0.040	0.018	7.1293	0.017	0.011	7.5000	7.0333	0.052	7.1667	7.8274	7.8304	7.8331	0.2580	0.2598	0.2615
45	7.6652	7.6666	7.6683	0.040	0.018	7.2960	0.017	0.011	7.6667	7.2000	0.052	7.3333	7.9895	7.9925	7.9952	0.2580	0.2598	0.2615
46	7.8318	7.8332	7.8349	0.040	0.018	7.4627	0.017	0.011	7.8333	7.3667	0.052	7.5000	8.1609	8.1639	8.1666	0.2580	0.2598	0.2615
47	7.9985	7.9999	8.0016	0.040	0.018	7.6293	0.017	0.011	8.0000	7.5333	0.052	7.6667	8.3231	8.3260	8.3288	0.2579	0.2597	0.2614
48	8.1652	8.1666	8.1683	0.040	0.018	7.7960	0.017	0.011	8.1667	7.7000	0.052	7.8333	8.4944	8.4973	8.5001	0.2579	0.2597	0.2614
49	8.3318	8.3332	8.3349	0.040	0.018	7.9627	0.017	0.011	8.3333	7.8667	0.052	8.0000	8.6569	8.6598	8.6626	0.2579	0.2597	0.2614
50	8.4985	8.4999	8.5017	0.040	0.018	8.1293	0.017	0.011	8.5000	8.0333	0.052	8.1667	8.8279	8.8309	8.8337	0.2579	0.2597	0.2614

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 10a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 11a—*8/16 Diametral Pitch, Internal*[a]

8/16 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0625 Dedendum (See Sec 6)	Circular Pitch, 0.3927 Meas-Pin Diam, 0.1800

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit				All fits	
					Flat-Root Side Fit										
						Major-diam fillet		Major diam						Measurement between pins	Space width
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad		Min effective 0.1963
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance→			+0.0007 + L[d] −0.0000	Min	+0.0035 −0.0000	App	Max	+0.0175 −0.0000	+0.0007 + L[d] −(0.0007 + L)	Min	+0.0035 −0.0000	+0.0175 −0.0000	Min[e]	Max	Dimensional Max[f]
6	0.7500	0.6495	0.8750	0.862	0.6595	0.018	0.007	0.9040	0.8750	0.8750	0.6595	0.9750	0.017	0.5549	0.1993
7	0.8750	0.7578	1.0000	0.985	0.7678	0.020	0.008	1.0290	1.0000	1.0000	0.7678	1.1000	0.021	0.6586	0.1994
8	1.0000	0.8660	1.1250	1.110	0.8890	0.021	0.008	1.1540	1.1250	1.1250	0.8890	1.2250	0.023	0.8051	0.1994
9	1.1250	0.9743	1.2500	1.233	1.0000	0.022	0.009	1.2790	1.2500	1.2500	1.0000	1.3500	0.024	0.9133	0.1994
10	1.2500	1.0825	1.3750	1.358	1.1250	0.023	0.009	1.4040	1.3750	1.3750	1.1250	1.4750	0.026	1.0553	0.1994
11	1.3750	1.1908	1.5000	1.481	1.2500	0.024	0.010	1.5290	1.5000	1.5000	1.2500	1.6000	0.027	1.1664	0.1994
12	1.5000	1.2990	1.6250	1.606	1.3750	0.024	0.010	1.6540	1.6250	1.6250	1.3750	1.7250	0.028	1.3053	0.1994
13	1.6250	1.4073	1.7500	1.731	1.5000	0.024	0.010	1.7790	1.7500	1.7500	1.5000	1.8500	0.028	1.4185	0.1994
14	1.7500	1.5156	1.8750	1.854	1.6250	0.025	0.011	1.9040	1.8750	1.8750	1.6250	1.9750	0.029	1.5553	0.1994
15	1.8750	1.6238	2.0000	1.979	1.7500	0.025	0.011	2.0290	2.0000	2.0000	1.7500	2.1000	0.030	1.6701	0.1994
16	2.0000	1.7321	2.1250	2.104	1.8750	0.025	0.011	2.1540	2.1250	2.1250	1.8750	2.2250	0.030	1.8053	0.1994
17	2.1250	1.8403	2.2500	2.229	2.0000	0.026	0.011	2.2790	2.2500	2.2500	2.0000	2.3500	0.031	1.9213	0.1994
18	2.2500	1.9486	2.3750	2.352	2.1250	0.026	0.012	2.4040	2.3750	2.3750	2.1250	2.4750	0.031	2.0553	0.1994
19	2.3750	2.0568	2.5000	2.477	2.2500	0.026	0.012	2.5290	2.5000	2.5000	2.2500	2.6000	0.031	2.1723	0.1994
20	2.5000	2.1651	2.6250	2.602	2.3750	0.026	0.012	2.6540	2.6250	2.6250	2.3750	2.7250	0.032	2.3053	0.1994
21	2.6250	2.2733	2.7500	2.727	2.5000	0.026	0.012	2.7790	2.7500	2.7500	2.5000	2.8500	0.032	2.4233	0.1995
22	2.7500	2.3816	2.8750	2.852	2.6250	0.026	0.012	2.9040	2.8750	2.8750	2.6250	2.9750	0.032	2.5556	0.1995
23	2.8750	2.4898	3.0000	2.977	2.7500	0.026	0.012	3.0290	3.0000	3.0000	2.7500	3.1000	0.032	2.6739	0.1995
24	3.0000	2.5981	3.1250	3.102	2.8750	0.027	0.012	3.1540	3.1250	3.1250	2.8750	3.2250	0.032	2.8056	0.1995
25	3.1250	2.7063	3.2500	3.227	3.0000	0.027	0.012	3.2790	3.2500	3.2500	3.0000	3.3500	0.033	2.9244	0.1995
26	3.2500	2.8146	3.3750	3.352	3.1250	0.027	0.012	3.4040	3.3750	3.3750	3.1250	3.4750	0.033	3.0555	0.1995
27	3.3750	2.9228	3.5000	3.475	3.2500	0.027	0.013	3.5290	3.5000	3.5000	3.2500	3.6000	0.033	3.1748	0.1995
28	3.5000	3.0311	3.6250	3.600	3.3750	0.027	0.013	3.6540	3.6250	3.6250	3.3750	3.7250	0.033	3.3055	0.1995
29	3.6250	3.1393	3.7500	3.725	3.5000	0.027	0.013	3.7790	3.7500	3.7500	3.5000	3.8500	0.033	3.4252	0.1995
30	3.7500	3.2476	3.8750	3.850	3.6250	0.027	0.013	3.9040	3.8750	3.8750	3.6250	3.9750	0.033	3.5555	0.1995
31	3.8750	3.3559	4.0000	3.975	3.7500	0.027	0.013	4.0290	4.0000	4.0000	3.7500	4.1000	0.033	3.6756	0.1995
32	4.0000	3.4641	4.1250	4.100	3.8750	0.027	0.013	4.1540	4.1250	4.1250	3.8750	4.2250	0.033	3.8055	0.1995
33	4.1250	3.5724	4.2500	4.225	4.0000	0.027	0.013	4.2790	4.2500	4.2500	4.0000	4.3500	0.034	3.9260	0.1995
34	4.2500	3.6806	4.3750	4.350	4.1250	0.027	0.013	4.4040	4.3750	4.3750	4.1250	4.4750	0.034	4.0555	0.1995
35	4.3750	3.7889	4.5000	4.475	4.2500	0.027	0.013	4.5290	4.5000	4.5000	4.2500	4.6000	0.034	4.1764	0.1996
36	4.5000	3.8971	4.6250	4.600	4.3750	0.027	0.013	4.6540	4.6250	4.6250	4.3750	4.7250	0.034	4.3058	0.1996
37	4.6250	4.0054	4.7500	4.725	4.5000	0.028	0.013	4.7790	4.7500	4.7500	4.5000	4.8500	0.034	4.4266	0.1996
38	4.7500	4.1136	4.8750	4.850	4.6250	0.028	0.013	4.9040	4.8750	4.8750	4.6250	4.9750	0.034	4.5558	0.1996
39	4.8750	4.2219	5.0000	4.975	4.7500	0.028	0.013	5.0290	5.0000	5.0000	4.7500	5.1000	0.034	4.6768	0.1996
40	5.0000	4.3301	5.1250	5.100	4.8750	0.028	0.013	5.1540	5.1250	5.1250	4.8750	5.2250	0.034	4.8058	0.1996
41	5.1250	4.4384	5.2500	5.225	5.0000	0.028	0.013	5.2790	5.2500	5.2500	5.0000	5.3500	0.034	4.9270	0.1996
42	5.2500	4.5466	5.3750	5.350	5.1250	0.028	0.013	5.4040	5.3750	5.3750	5.1250	5.4750	0.034	5.0558	0.1996
43	5.3750	4.6549	5.5000	5.475	5.2500	0.028	0.013	5.5290	5.5000	5.5000	5.2500	5.6000	0.034	5.1772	0.1996
44	5.5000	4.7631	5.6250	5.600	5.3750	0.028	0.013	5.6540	5.6250	5.6250	5.3750	5.7250	0.034	5.3058	0.1996
45	5.6250	4.8714	5.7500	5.725	5.5000	0.028	0.013	5.7790	5.7500	5.7500	5.5000	5.8500	0.034	5.4274	0.1996
46	5.7500	4.9797	5.8750	5.850	5.6250	0.028	0.013	5.9040	5.8750	5.8750	5.6250	5.9750	0.034	5.5558	0.1996
47	5.8750	5.0879	6.0000	5.975	5.7500	0.028	0.013	6.0290	6.0000	6.0000	5.7500	6.1000	0.034	5.6775	0.1966
48	6.0000	5.1962	6.1250	6.100	5.8750	0.028	0.013	6.1540	6.1250	6.1250	5.8750	6.2250	0.034	5.8058	0.1996
49	6.1250	5.3044	6.2500	6.225	6.0000	0.028	0.013	6.2790	6.2500	6.2500	6.0000	6.3500	0.034	5.9277	0.1997
50	6.2500	5.4127	6.3750	6.350	6.1250	0.028	0.013	6.4040	6.3750	6.3750	6.1250	6.4750	0.034	6.0559	0.1997

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2)and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 11b—8/16 *Diametral Pitch, External*[a]

8/16 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0625 Dedendum (See Sec 6)	Circular Pitch, 0.3927 Meas-Pin Diam, 0.2400

EXTERNAL

	Major-diameter fit[b]								Fillet root[c]			Dimensions for all fits					
						Flat-root side fit									Tooth thickness		
N	Major diameter			Major-diam chamfer		Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.1958	0.1976	0.1993
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J^e)	+0.0000 −(0.0006 + J^e)	+0.0009 + J^e −0.0000	App	Min	+0.0000 −0.0175	App	Max	+0.0000 −0.0070	+0.0000 −0.0175	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.8735	0.8749	0.8759	0.029	0.011	0.5960	0.021	0.021	0.8750	0.5252	—	0.6595	1.1036	1.1060	1.1082	0.1927	0.1945	0.1962
7	0.9985	0.9999	1.0009	0.029	0.012	0.7210	0.019	0.019	1.0000	0.6500	—	0.7678	1.2055	1.2079	1.2101	0.1927	0.1945	0.1962
8	1.1235	1.1249	1.1259	0.029	0.012	0.8460	0.018	0.017	1.1250	0.7750	0.047	0.8890	1.3569	1.3593	1.3617	0.1297	0.1945	0.1962
9	1.2485	1.2499	1.2509	0.029	0.012	0.9710	0.016	0.016	1.2500	0.9000	0.046	1.0000	1.4643	1.4667	1.4691	0.1927	0.1945	0.1962
10	1.3735	1.3749	1.3759	0.029	0.012	1.0960	0.015	0.015	1.3750	1.0250	0.045	1.1250	1.6091	1.6116	1.6140	0.1926	0.1944	0.1961
11	1.4985	1.4999	1.5010	0.029	0.012	1.2210	0.015	0.014	1.5000	1.1500	0.044	1.2500	1.7198	1.7223	1.7247	0.1926	0.1944	0.1961
12	1.6235	1.6249	1.6260	0.029	0.013	1.3460	0.014	0.013	1.6250	1.2750	0.044	1.3750	1.8609	1.8635	1.8659	0.1926	0.1944	0.1961
13	1.7485	1.7499	1.7510	0.029	0.013	1.4710	0.014	0.013	1.7500	1.4000	0.043	1.5000	1.9739	1.9765	1.9789	0.1926	0.1944	0.1961
14	1.8735	1.8749	1.8760	0.029	0.013	1.5960	0.013	0.012	1.8750	1.5250	0.043	1.6250	2.1123	2.1149	2.1174	0.1926	0.1944	0.1961
15	1.9985	1.9999	2.0010	0.030	0.013	1.7210	0.013	0.012	2.0000	1.6500	0.042	1.7500	2.2269	2.2295	2.2320	0.1926	0.1944	0.1961
16	2.1235	2.1249	2.1260	0.030	0.013	1.8460	0.013	0.011	2.1250	1.7750	0.042	1.8750	2.3633	2.3660	2.3685	0.1926	0.1944	0.1961
17	2.2485	2.2499	2.2510	0.030	0.013	1.9710	0.013	0.011	2.2500	1.9000	0.042	2.0000	2.4792	2.4819	2.4844	0.1926	0.1944	0.1961
18	2.3735	2.3749	2.3760	0.030	0.013	2.0960	0.013	0.011	2.3750	2.0250	0.042	2.1250	2.6142	2.6169	2.6195	0.1926	0.1944	0.1961
19	2.4985	2.4999	2.5011	0.030	0.013	2.2210	0.013	0.011	2.5000	2.1500	0.041	2.2500	2.7311	2.7338	2.7364	0.1296	0.1944	0.1961
20	2.6235	2.6249	2.6261	0.030	0.013	2.3460	0.013	0.011	2.6250	2.2750	0.041	2.3750	2.8650	2.8677	2.8703	0.1926	0.1944	0.1961
21	2.7485	2.7499	2.7511	0.030	0.013	2.4710	0.013	0.010	2.7500	2.4000	0.041	2.5000	2.9827	2.9854	2.9880	0.1926	0.1944	0.1961
22	2.8735	2.8749	2.8761	0.030	0.013	2.5960	0.013	0.010	2.8750	2.5250	0.041	2.6250	3.1156	3.1184	3.1210	0.1926	0.1944	0.1961
23	2.9985	2.9999	3.0011	0.030	0.013	2.7210	0.013	0.010	3.0000	2.6500	0.041	2.7500	3.2339	3.2367	3.2393	0.1926	0.1944	0.1961
24	3.1235	3.1249	3.1261	0.030	0.013	2.8460	0.013	0.010	3.1250	2.7750	0.040	2.8750	3.3662	3.3690	3.3716	0.1926	0.1944	0.1961
25	3.2485	3.2499	3.2511	0.030	0.013	2.9710	0.013	0.010	3.2500	2.9000	0.040	3.0000	3.4850	3.4878	3.4904	0.1926	0.1944	0.1961
26	3.3735	3.3749	3.3761	0.030	0.013	3.0960	0.013	0.010	3.3750	3.0250	0.040	3.1250	3.6166	3.6194	3.6221	0.1926	0.1944	0.1961
27	3.4985	3.4999	3.5012	0.030	0.013	3.2210	0.013	0.010	3.5000	3.1500	0.040	3.2500	3.7359	3.7387	3.7414	0.1926	0.1944	0.1961
28	3.6235	3.6249	3.6262	0.030	0.013	3.3460	0.013	0.010	3.6250	3.2750	0.040	3.3750	3.8669	3.8698	3.8724	0.1925	0.1943	0.1960
29	3.7485	3.7499	3.7512	0.030	0.013	3.4710	0.013	0.009	3.7500	3.4000	0.040	3.5000	3.9866	3.9895	3.9921	0.1925	0.1943	0.1960
30	3.8735	3.8749	3.8762	0.030	0.013	3.5960	0.013	0.009	3.8750	3.5250	0.040	3.6250	4.1173	4.1201	4.1228	0.1925	0.1943	0.1960
31	3.9985	3.9999	4.0012	0.030	0.013	3.7210	0.013	0.009	4.0000	3.6500	0.039	3.7500	4.2373	4.2401	4.2428	0.1925	0.1943	0.1960
32	4.1235	4.1249	4.1262	0.030	0.013	3.8460	0.013	0.009	4.1250	3.7750	0.039	3.8750	4.3676	4.3704	4.3731	0.1925	0.1943	0.1960
33	4.2485	4.2499	4.2512	0.030	0.013	3.9710	0.013	0.009	4.2500	3.9000	0.039	4.0000	4.4880	4.4908	4.4935	0.1925	0.1943	0.1960
34	4.3735	4.3749	4.3762	0.030	0.013	4.0960	0.013	0.009	4.3750	4.0250	0.039	4.1250	4.6179	4.6208	4.6235	0.1925	0.1943	0.1960
35	4.4985	4.4999	4.5013	0.030	0.013	4.2210	0.013	0.008	4.5000	4.1500	0.039	4.2500	4.7385	4.7414	4.7441	0.1925	0.1943	0.1960
36	4.6235	4.6249	4.6263	0.030	0.013	4.3460	0.013	0.008	4.6250	4.2750	0.039	4.3750	4.8681	4.8710	4.8737	0.1925	0.1943	0.1960
37	4.7485	4.7499	4.7513	0.030	0.013	4.4710	0.013	0.008	4.7500	4.4000	0.039	4.5000	4.9890	4.9919	4.9946	0.1925	0.1943	0.1960
38	4.8735	4.8749	4.8763	0.030	0.013	4.5960	0.013	0.008	4.8750	4.5250	0.039	4.6250	5.1184	5.1213	5.1240	0.1925	0.1943	0.1960
39	4.9985	4.9999	5.0013	0.030	0.013	4.7210	0.013	0.008	5.0000	4.6500	0.039	4.7500	5.2395	5.2424	5.2451	0.1925	0.1943	0.1960
40	5.1235	5.1249	5.1263	0.030	0.013	4.8460	0.013	0.008	5.1250	4.7750	0.039	4.8750	5.3687	5.3716	5.3743	0.1925	0.1943	0.1960
41	5.2485	5.2499	5.2513	0.030	0.013	4.9710	0.013	0.008	5.2500	4.9000	0.039	5.0000	5.4899	5.4928	5.4955	0.1925	0.1943	0.1960
42	5.3735	5.3749	5.3763	0.030	0.013	5.0960	0.013	0.008	5.3750	5.0250	0.039	5.1250	5.6184	5.6213	5.6240	0.1925	0.1943	0.1960
43	5.4985	5.4999	5.5014	0.030	0.013	5.2210	0.013	0.008	5.5000	5.1500	0.039	5.2500	5.7403	5.7432	5.7459	0.1925	0.1943	0.1960
44	5.6235	5.6249	5.6264	0.030	0.013	5.3460	0.013	0.008	5.6250	5.2750	0.039	5.3750	5.8690	5.8720	5.8747	0.1925	0.1943	0.1960
45	5.7485	5.7499	5.7514	0.030	0.013	5.4710	0.013	0.008	5.7500	5.4000	0.039	5.5000	5.9906	5.9936	5.9963	0.1925	0.1943	0.1960
46	5.8735	5.8749	5.8764	0.030	0.013	5.5960	0.013	0.008	5.8750	5.5250	0.038	5.6250	6.1191	6.1221	6.1248	0.1925	0.1943	0.1960
47	5.9985	5.9999	6.0014	0.030	0.013	5.7210	0.013	0.008	6.0000	5.6500	0.038	5.7500	6.2408	6.2437	6.2465	0.1924	0.1942	0.1959
48	6.1235	6.1249	6.1264	0.030	0.013	5.8460	0.013	0.008	6.1250	5.7750	0.038	5.8750	6.3692	6.3721	6.3749	0.1924	0.1942	0.1959
49	6.2485	6.2499	6.2514	0.030	0.013	5.9710	0.013	0.008	6.2500	5.9000	0.038	6.0000	6.4911	6.4940	6.4968	0.1924	0.1942	0.1959
50	6.3735	6.3479	6.3764	0.030	0.013	6.0960	0.013	0.008	6.3750	6.0250	0.038	6.1250	6.6193	6.6223	6.6251	0.1924	0.1942	0.1959

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 11a, footnote c.
[e] $J = 0.0002 \times$ diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60 %of the lead error from this dimension (see Table 27).

TABLE 12a—*10/20 Diametral Pitch, Internal*[a]

10/20 Diametral Pitch
Pressure Angle, 30°

Addendum (Basic), 0.0500
Dedendum (See Sec 6)

Circular Pitch, 0.3142
Meas-Pin Diam, 0.1440

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits		
					Flat-Root Side Fit										
						Major-diam fillet		Major diam							Space width
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad	Measurement between pins	Min effective 0.1571
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance→			+0.0007 + L[d] −0.0000	Min	+0.0025 −0.0000	App	Max	+0.0150 −0.0000	+0.0007 + L[d] −(0.0007 + L)	Min	+0.0025 −0.0000	+0.0150 −0.0000	Min[e]	Max	Dimensional Max[f]
6	0.6000	0.5196	0.7000	0.691	0.5296	0.015	0.005	0.7240	0.7000	0.7000	0.5296	0.7800	0.012	0.4439	0.1595
7	0.7000	0.6062	0.8000	0.789	0.6162	0.016	0.006	0.8240	0.8000	0.8000	0.6162	0.8800	0.016	0.5269	0.1596
8	0.8000	0.6928	0.9000	0.887	0.7100	0.017	0.007	0.9240	0.9000	0.9000	0.7100	0.9800	0.018	0.6441	0.1596
9	0.9000	0.7794	1.0000	0.987	0.8000	0.017	0.007	1.0240	1.0000	1.0000	0.8000	1.0800	0.019	0.7307	0.1596
10	1.0000	0.8660	1.1000	1.085	0.9000	0.018	0.008	1.1240	1.1000	1.1000	0.9000	1.1800	0.020	0.8443	0.1596
11	1.1000	0.9526	1.2000	1.185	1.0000	0.019	0.008	1.2240	1.2000	1.2000	1.0000	1.2800	0.021	0.9332	0.1596
12	1.2000	1.0392	1.3000	1.285	1.1000	0.019	0.008	1.3240	1.3000	1.3000	1.1000	1.3800	0.022	1.0442	0.1596
13	1.3000	1.1258	1.4000	1.385	1.2000	0.020	0.008	1.4240	1.4000	1.4000	1.2000	1.4800	0.022	1.1349	0.1596
14	1.4000	1.2124	1.5000	1.483	1.3000	0.020	0.009	1.5240	1.5000	1.5000	1.3000	1.5800	0.023	1.2443	0.1596
15	1.5000	1.2990	1.6000	1.583	1.4000	0.020	0.009	1.6240	1.6000	1.6000	1.4000	1.6800	0.023	1.3362	0.1596
16	1.6000	1.3856	1.7000	1.683	1.5000	0.020	0.009	1.7240	1.7000	1.7000	1.5000	1.7800	0.024	1.4443	0.1596
17	1.7000	1.4722	1.8000	1.783	1.6000	0.020	0.009	1.8240	1.8000	1.8000	1.6000	1.8800	0.024	1.5371	0.1596
18	1.8000	1.5588	1.9000	1.883	1.7000	0.021	0.009	1.9240	1.9000	1.9000	1.7000	1.9800	0.024	1.6444	0.1596
19	1.9000	1.6454	2.0000	1.983	1.8000	0.021	0.009	2.0240	2.0000	2.0000	1.8000	2.0800	0.024	1.7379	0.1596
20	2.0000	1.7321	2.1000	2.081	1.9000	0.021	0.010	2.1240	2.1000	2.1000	1.9000	2.1800	0.025	1.8443	0.1596
21	2.1000	1.8187	2.2000	2.181	2.0000	0.021	0.010	2.2240	2.2000	2.2000	2.0000	2.2800	0.025	1.9387	0.1597
22	2.2000	1.9053	2.3000	2.281	2.1000	0.021	0.010	2.3240	2.3000	2.3000	2.1000	2.3800	0.025	2.0445	0.1597
23	2.3000	1.9919	2.4000	2.381	2.2000	0.021	0.010	2.4240	2.4000	2.4000	2.2000	2.4800	0.025	2.1392	0.1597
24	2.4000	2.0785	2.5000	2.481	2.3000	0.021	0.010	2.5240	2.5000	2.5000	2.3000	2.5800	0.026	2.2445	0.1597
25	2.5000	2.1651	2.6000	2.581	2.4000	0.021	0.010	2.6240	2.6000	2.6000	2.4000	2.6800	0.026	2.3396	0.1597
26	2.6000	2.2517	2.7000	2.681	2.5000	0.021	0.010	2.7240	2.7000	2.7000	2.5000	2.7800	0.026	2.4445	0.1597
27	2.7000	2.3383	2.8000	2.781	2.6000	0.021	0.010	2.8240	2.8000	2.8000	2.6000	2.8800	0.026	2.5400	0.1597
28	2.8000	2.4249	2.9000	2.881	2.7000	0.022	0.010	2.9240	2.9000	2.9000	2.7000	2.9800	0.026	2.6445	0.1597
29	2.9000	2.5115	3.0000	2.981	2.8000	0.022	0.010	3.0240	3.0000	3.0000	2.8000	3.0800	0.026	2.7403	0.1597
30	3.0000	2.5981	3.1000	3.081	2.9000	0.022	0.010	3.1240	3.1000	3.1000	2.9000	3.1800	0.026	2.8445	0.1597
31	3.1000	2.6847	3.2000	3.181	3.0000	0.022	0.010	3.2240	3.2000	3.2000	3.0000	3.2800	0.026	2.9406	0.1597
32	3.2000	2.7713	3.3000	3.281	3.1000	0.022	0.010	3.3240	3.3000	3.3000	3.1000	3.3800	0.026	3.0446	0.1597
33	3.3000	2.8579	3.4000	3.381	3.2000	0.022	0.010	3.4240	3.4000	3.4000	3.2000	3.4800	0.026	3.1409	0.1597
34	3.4000	2.9445	3.5000	3.481	3.3000	0.022	0.010	3.5240	3.5000	3.5000	3.3000	3.5800	0.027	3.2446	0.1597
35	3.5000	3.0311	3.6000	3.581	3.4000	0.022	0.010	3.6240	3.6000	3.6000	3.4000	3.6800	0.027	3.3412	0.1597
36	3.6000	3.1177	3.7000	3.681	3.5000	0.022	0.010	3.7240	3.7000	3.7000	3.5000	3.7800	0.027	3.4447	0.1598
37	3.7000	3.2043	3.8000	3.781	3.6000	0.022	0.010	3.8240	3.8000	3.8000	3.6000	3.8800	0.027	3.5413	0.1598
38	3.8000	3.2909	3.9000	3.879	3.7000	0.022	0.011	3.9240	3.9000	3.9000	3.7000	3.9800	0.027	3.6447	0.1598
39	3.9000	3.3775	4.0000	3.979	3.8000	0.022	0.011	4.0240	4.0000	4.0000	3.8000	4.0800	0.027	3.7415	0.1598
40	4.0000	3.4641	4.1000	4.079	3.9000	0.022	0.011	4.1240	4.1000	4.1000	3.9000	4.1800	0.027	3.8447	0.1598
41	4.1000	3.5507	4.2000	4.179	4.0000	0.022	0.011	4.2240	4.2000	4.2000	4.0000	4.2800	0.027	3.9416	0.1598
42	4.2000	3.6373	4.3000	4.279	4.1000	0.022	0.011	4.3240	4.3000	4.3000	4.1000	4.3800	0.027	4.0447	0.1598
43	4.3000	3.7239	4.4000	4.379	4.2000	0.022	0.011	4.4240	4.4000	4.4000	4.2000	4.4800	0.027	4.1418	0.1598
44	4.4000	3.8105	4.5000	4.479	4.3000	0.022	0.011	4.5240	4.5000	4.5000	4.3000	4.5800	0.027	4.2447	0.1598
45	4.5000	3.8971	4.6000	4.579	4.4000	0.022	0.011	4.6240	4.6000	4.6000	4.4000	4.6800	0.027	4.3420	0.1598
46	4.6000	3.9837	4.7000	4.679	4.5000	0.022	0.011	4.7240	4.7000	4.7000	4.5000	4.7800	0.027	4.4447	0.1598
47	4.7000	4.0703	4.8000	4.779	4.6000	0.022	0.011	4.8240	4.8000	4.8000	4.6000	4.8800	0.027	4.5420	0.1598
48	4.8000	4.1569	4.9000	4.879	4.7000	0.022	0.011	4.9240	4.9000	4.9000	4.7000	4.9800	0.027	4.6447	0.1598
49	4.9000	4.2435	5.0000	4.979	4.8000	0.022	0.011	5.0240	5.0000	5.0000	4.8000	5.0800	0.027	4.7424	0.1599
50	5.0000	4.3301	5.1000	5.079	4.9000	0.022	0.011	5.1240	5.1000	5.1000	4.9000	5.1800	0.027	4.8449	0.1599

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 12b—*10/20 Diametral Pitch, External*[a]

10/20 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0500 Dedendum (See Sec 6)	Circular Pitch, 0.3142 Meas-Pin Diam, 0.1920

EXTERNAL

	Major-diameter fit[b]								Fillet root[c]		Dimensions for all fits							
						Flat-root side fit									Tooth thickness		
N	Major diameter			Major-diam chamfer		Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.1566	0.1582	0.1601
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J[e])	+0.0000 −(0.0006 + J[e])	+0.0009 + J[e] −0.0000	App	Min	+0.0000 −0.0170	App	Max	+0.0000 −0.0025	+0.0000 −0.0170	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.6985	0.6999	0.7009	0.023	0.009	0.4760	0.017	0.017	0.7000	0.4200	—	0.5296	0.8820	0.8861	0.8866	0.1536	0.1552	0.1571
7	0.7985	0.7999	0.8009	0.023	0.009	0.5760	0.015	0.015	0.8000	0.5200	—	0.6162	0.9636	0.9657	0.9682	0.1536	0.1552	0.1571
8	0.8985	0.8999	0.9009	0.023	0.009	0.6760	0.014	0.014	0.9000	0.6200	0.037	0.7100	1.0846	1.0868	1.0894	0.1536	0.1552	0.1571
9	0.9985	0.9999	1.0009	0.023	0.010	0.7760	0.013	0.013	1.0000	0.7200	0.037	0.8000	1.1706	1.1728	1.1754	0.1536	0.1552	0.1571
10	1.0985	1.0999	1.1009	0.023	0.010	0.8760	0.012	0.012	1.1000	0.8200	0.036	0.9000	1.2863	1.2886	1.2913	0.1535	0.1551	0.1570
11	1.1985	1.1999	1.2009	0.023	0.010	0.9760	0.012	0.011	1.2000	0.9200	0.035	1.0000	1.3749	1.3772	1.3799	0.1535	0.1551	0.1570
12	1.2985	1.2999	1.3009	0.023	0.010	1.0760	0.011	0.011	1.3000	1.0200	0.035	1.1000	1.4878	1.4901	1.4929	0.1535	0.1551	0.1570
13	1.3985	1.3999	1.4009	0.023	0.010	1.1760	0.011	0.010	1.4000	1.1200	0.035	1.2000	1.5782	1.5805	1.5833	0.1535	0.1551	0.1570
14	1.4985	1.4999	1.5010	0.023	0.010	1.2760	0.010	0.010	1.5000	1.2200	0.034	1.3000	1.6888	1.6912	1.6940	0.1535	0.1551	0.1570
15	1.5985	1.5999	1.6010	0.024	0.010	1.3760	0.010	0.010	1.6000	1.3200	0.034	1.4000	1.7805	1.7829	1.7857	0.1535	0.1551	0.1570
16	1.6985	1.6999	1.7010	0.024	0.010	1.4760	0.010	0.009	1.7000	1.4200	0.033	1.5000	1.8897	1.8921	1.8950	0.1535	0.1551	0.1570
17	1.7985	1.7999	1.8010	0.024	0.010	1.5760	0.010	0.009	1.8000	1.5200	0.033	1.6000	1.9824	1.9848	1.9877	0.1535	0.1551	0.1570
18	1.8985	1.8999	1.9010	0.024	0.010	1.6760	0.010	0.009	1.9000	1.6200	0.033	1.7000	2.0904	2.0928	2.0956	0.1535	0.1551	0.1570
19	1.9985	1.9999	2.0010	0.024	0.010	1.7760	0.010	0.009	2.0000	1.7200	0.033	1.8000	2.1839	2.1863	2.1891	0.1535	0.1551	0.1570
20	2.0985	2.0999	2.1010	0.024	0.010	1.8760	0.010	0.009	2.1000	1.8200	0.033	1.9000	2.2910	2.2935	2.2963	0.1535	0.1551	0.1570
21	2.1985	2.1999	2.2010	0.024	0.010	1.9760	0.010	0.008	2.2000	2.9200	0.032	2.0000	2.3851	2.3875	2.3904	0.1535	0.1551	0.1570
22	2.2985	2.2999	2.3010	0.024	0.010	2.0760	0.010	0.008	2.3000	2.0200	0.032	2.1000	2.4915	2.4939	2.4968	0.1535	0.1551	0.1570
23	2.3985	2.3999	2.4010	0.024	0.010	2.1760	0.010	0.008	2.4000	2.1200	0.032	2.2000	2.5862	2.5886	2.5915	0.1535	0.1551	0.1570
24	2.4985	2.4999	2.5011	0.024	0.011	2.2760	0.010	0.008	2.5000	2.2200	0.032	2.3000	2.6919	2.6944	2.6973	0.1535	0.1551	0.1570
25	2.5985	2.5999	2.6011	0.024	0.011	2.3760	0.010	0.008	2.6000	3.3200	0.032	2.4000	2.7870	2.7895	2.7924	0.1535	0.1551	0.1570
26	2.6985	2.6999	2.7011	0.024	0.011	2.4760	0.010	0.008	2.7000	2.4200	0.032	2.5000	2.8923	2.8948	2.8977	0.1535	0.1551	0.1570
27	2.7985	2.7999	2.8011	0.024	0.011	2.5760	0.010	0.008	2.8000	2.5200	0.032	2.6000	2.9878	2.9903	2.9932	0.1535	0.1551	0.1570
28	2.8985	2.8999	2.9011	0.024	0.011	2.6760	0.010	0.008	2.9000	2.6200	0.032	2.7000	3.0925	3.0950	3.0980	0.1534	0.1550	0.1569
29	2.9985	2.9999	3.0011	0.024	0.011	2.7760	0.010	0.008	3.0000	2.7200	0.031	2.8000	3.1883	3.1908	3.1938	0.1534	0.1550	0.1569
30	3.0985	3.0999	3.1011	0.024	0.011	2.8760	0.010	0.007	3.1000	2.8200	0.031	2.9000	3.2928	3.2953	3.2983	0.1534	0.1550	0.1569
31	3.1985	3.1999	3.2011	0.024	0.011	2.9760	0.010	0.007	3.2000	2.9200	0.031	3.0000	3.3889	3.3914	3.3944	0.1534	0.1550	0.1569
32	3.2985	3.2999	3.3011	0.024	0.011	3.0760	0.010	0.007	3.3000	3.0200	0.031	3.1000	3.4930	3.4955	3.4986	0.1534	0.1550	0.1569
33	3.3985	3.3999	3.4011	0.024	0.011	3.1760	0.010	0.007	3.4000	3.1200	0.031	3.2000	3.5893	3.5918	3.5949	0.1534	0.1550	0.1569
34	3.4985	3.4999	3.5012	0.024	0.011	3.2760	0.010	0.007	3.5000	3.2200	0.031	3.3000	3.6933	3.6958	3.6989	0.1534	0.1550	0.1569
35	3.5985	3.5999	3.6012	0.024	0.011	3.3760	0.010	0.007	3.6000	3.3200	0.031	3.4000	3.7898	3.7923	3.7954	0.1534	0.1550	0.1569
36	3.6985	3.6999	3.7012	0.024	0.011	3.4760	0.010	0.007	3.7000	3.4200	0.031	3.5000	3.8935	3.8960	3.8991	0.1534	0.1550	0.1569
37	3.7985	3.7999	3.8012	0.024	0.011	3.5760	0.010	0.007	3.8000	3.5200	0.031	3.6000	3.9902	3.9927	3.9958	0.1534	0.1550	0.1569
38	3.8985	3.8999	3.9012	0.024	0.011	3.6760	0.010	0.007	3.9000	3.6200	0.031	3.7000	4.0937	4.0962	4.0993	0.1534	0.1550	0.1569
39	3.9985	3.9999	4.0012	0.024	0.011	3.7760	0.010	0.007	4.0000	3.7200	0.031	3.8000	4.1906	4.1931	4.1962	0.1534	0.1550	0.1569
40	4.0985	4.0999	4.1012	0.024	0.011	3.8760	0.010	0.007	4.1000	3.8200	0.031	3.9000	4.2938	4.2964	4.2995	0.1534	0.1550	0.1569
41	4.1985	4.1999	4.2012	0.024	0.011	3.9760	0.010	0.007	4.2000	3.9200	0.031	4.0000	4.3908	4.3934	4.3965	0.1534	0.1550	0.1569
42	4.2985	4.2999	4.3012	0.024	0.011	4.0760	0.010	0.007	4.3000	4.0200	0.031	4.1000	4.4940	4.4966	4.4997	0.1534	0.1550	0.1569
43	4.3985	4.3999	4.4012	0.024	0.011	4.1760	0.010	0.007	4.4000	4.1200	0.031	4.2000	4.5911	4.5937	4.5968	0.1534	0.1550	0.1569
44	4.4985	4.4999	4.5013	0.024	0.011	4.2760	0.010	0.007	4.5000	4.2200	0.031	4.3000	4.6941	4.6967	4.6998	0.1534	0.1550	0.1569
45	4.5985	4.5999	4.6013	0.024	0.011	4.3760	0.010	0.007	4.6000	4.3200	0.031	4.4000	4.7914	4.7940	4.7971	0.1534	0.1550	0.1569
46	4.6985	4.6999	4.7013	0.024	0.011	4.4760	0.010	0.007	4.7000	4.4200	0.031	4.5000	4.8943	4.8969	4.9000	0.1534	0.1550	0.1569
47	4.7985	4.7999	4.8013	0.024	0.011	4.5760	0.010	0.007	4.8000	4.5200	0.030	4.6000	4.9915	4.9941	4.9972	0.1533	0.1549	0.1568
48	4.8985	4.8999	4.9013	0.024	0.011	4.6760	0.010	0.007	4.9000	4.6200	0.030	4.7000	5.0942	5.0968	5.0999	0.1533	0.1549	0.1568
49	4.9985	4.9999	5.0013	0.024	0.011	4.7760	0.010	0.007	5.0000	4.7200	0.030	4.8000	5.1917	5.1943	5.1974	0.1533	0.1549	0.1568
50	5.0985	5.0999	5.1013	0.024	0.011	4.8760	0.010	0.007	5.1000	4.8200	0.030	4.9000	5.2944	5.2970	5.3001	0.1533	0.1549	0.1568

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 12a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 13a—*12/24 Diametral Pitch, Internal*[a]

12/24 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0417 Dedendum (See Sec 6)	Circular Pitch, 0.2618 Meas-Pin Diam, 0.1200

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit				All fits	
					Flat-Root Side Fit										
						Major-diam fillet		Major diam						Measurement between pins	Space width
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad		Min effective 0.1309
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance→			$+0.0007 + L^d$ -0.0000	Min	$+0.0025$ -0.0000	App	Max	$+0.0133$ -0.0000	$+0.0007 + L^d$ $-(0.0007 + L)$	Min	$+0.0025$ -0.0000	$+0.0133$ -0.0000	Min[e]	Max	Dimensional Max[f]
6	0.5000	0.4330	0.5833	0.576	0.4430	0.012	0.004	0.6040	0.5833	0.5833	0.4430	0.6500	0.011	0.3707	0.1333
7	0.5833	0.5052	0.6667	0.658	0.5152	0.013	0.005	0.6873	0.6667	0.6667	0.5152	0.7333	0.013	0.4399	0.1334
8	0.6667	0.5774	0.7500	0.739	0.5833	0.014	0.006	0.7707	0.7500	0.7500	0.5833	0.8167	0.014	0.5375	0.1334
9	0.7500	0.6495	0.8333	0.822	0.6667	0.015	0.006	0.8540	0.8333	0.8333	0.6667	0.9000	0.015	0.6097	0.1334
10	0.8333	0.7217	0.9167	0.906	0.7500	0.015	0.006	0.9373	0.9167	0.9167	0.7500	0.9833	0.016	0.7043	0.1334
11	0.9167	0.7939	1.0000	0.987	0.8333	0.016	0.007	1.0207	1.0000	1.0000	0.8333	1.0667	0.017	0.7767	0.1334
12	1.0000	0.8660	1.0833	1.070	0.9167	0.016	0.007	1.1040	1.0833	1.0833	0.9167	1.1500	0.017	0.8709	0.1334
13	1.0833	0.9382	1.1667	1.154	1.0000	0.016	0.007	1.1873	1.1667	1.1667	1.0000	1.2333	0.018	0.9465	0.1334
14	1.1667	1.0104	1.2500	1.237	1.0833	0.017	0.007	1.2707	1.2500	1.2500	1.0833	1.3167	0.018	1.0377	0.1334
15	1.2500	1.0825	1.3333	1.320	1.1667	0.017	0.007	1.3540	1.3333	1.3333	1.1667	1.4000	0.019	1.1142	0.1334
16	1.3333	1.1547	1.4167	1.402	1.2500	0.017	0.008	1.4373	1.4167	1.4167	1.2500	1.4833	0.019	1.2044	0.1334
17	1.4167	1.2269	1.5000	1.485	1.3333	0.017	0.008	1.5207	1.5000	1.5000	1.3333	1.5667	0.019	1.2816	0.1334
18	1.5000	1.2990	1.5833	1.568	1.4167	0.017	0.008	1.6040	1.5833	1.5833	1.4167	1.6500	0.020	1.3710	0.1334
19	1.5833	1.3712	1.6667	1.652	1.5000	0.017	0.008	1.6873	1.6667	1.6667	1.5000	1.7333	0.020	1.4489	0.1334
20	1.6667	1.4434	1.7500	1.735	1.5833	0.017	0.008	1.7707	1.7500	1.7500	1.5833	1.8167	0.020	1.5376	0.1334
21	1.7500	1.5155	1.8333	1.818	1.6667	0.018	0.008	1.8540	1.8333	1.8333	1.6667	1.9000	0.020	1.6164	0.1335
22	1.8333	1.5877	1.9167	1.902	1.7500	0.018	0.008	1.9373	1.9167	1.9167	1.7500	1.9833	0.020	1.7045	0.1335
23	1.9167	1.6599	2.0000	1.985	1.8333	0.018	0.008	2.0207	2.0000	2.0000	1.8333	2.0667	0.021	1.7834	0.1335
24	2.0000	1.7321	2.0833	2.068	1.9167	0.018	0.008	2.1040	2.0833	2.0833	1.9167	2.1500	0.021	1.8712	0.1335
25	2.0833	1.8042	2.1667	2.152	2.0000	0.018	0.008	2.1873	2.1667	2.1667	2.0000	2.2333	0.021	1.9504	0.1335
26	2.1667	1.8764	2.2500	2.235	2.0833	0.018	0.008	2.2707	2.2500	2.2500	2.0833	2.3167	0.021	2.0379	0.1335
27	2.2500	1.9486	2.3333	2.318	2.1667	0.018	0.008	2.3540	2.3333	2.3333	2.1667	2.4000	0.021	2.1174	0.1335
28	2.3333	2.0207	2.4167	2.402	2.2500	0.018	0.008	2.4373	2.4167	2.1467	2.2500	2.4833	0.021	2.2045	0.1335
29	2.4167	2.0929	2.5000	2.485	2.3333	0.018	0.008	2.5207	2.5000	2.5000	2.3333	2.5667	0.021	2.2838	0.1335
30	2.5000	2.1651	2.5833	2.566	2.4167	0.018	0.009	2.6040	2.5833	2.5833	2.4167	2.6500	0.021	2.3712	0.1335
31	2.5833	2.2372	2.6667	2.650	2.5000	0.018	0.009	2.6873	2.6667	2.6667	2.5000	2.7333	0.022	2.4512	0.1335
32	2.6667	2.3094	2.7500	2.733	2.5833	0.018	0.009	2.7707	2.7500	2.7500	2.5833	2.8167	0.022	2.5379	0.1335
33	2.7500	2.3816	2.8333	2.816	2.6667	0.018	0.009	2.8540	2.8333	2.8333	2.6667	2.9000	0.022	2.6182	0.1335
34	2.8333	2.4537	2.9167	2.900	2.7500	0.018	0.009	2.9373	2.9167	2.9167	2.7500	2.9833	0.022	2.7046	0.1335
35	2.9167	2.5259	3.0000	2.983	2.8333	0.018	0.009	3.0207	3.0000	3.0000	2.8333	3.0667	0.022	2.7851	0.1336
36	3.0000	2.5981	3.0833	3.066	2.9167	0.018	0.009	3.1040	3.0833	3.0833	2.9167	3.1500	0.022	2.8713	0.1336
37	3.0833	2.6702	3.1667	3.150	3.0000	0.018	0.009	3.1873	3.1667	3.1667	3.0000	3.2333	0.022	2.9519	0.1336
38	3.1667	2.7424	3.2500	3.233	3.0833	0.018	0.009	3.2707	3.2500	3.2500	3.0833	3.3167	0.022	3.0380	0.1336
39	3.2500	2.8146	3.3333	3.316	3.1667	0.018	0.009	3.3540	3.3333	3.3333	3.1667	3.4000	0.022	3.1187	0.1336
40	3.3333	2.8867	3.4167	3.400	3.2500	0.018	0.009	3.4373	3.4167	3.1467	3.2500	3.4833	0.022	3.2047	0.1336
41	3.4167	2.9589	3.5000	3.483	3.3333	0.018	0.009	3.5207	3.5000	3.5000	3.3333	3.5667	0.022	3.2855	0.1336
42	3.5000	3.0311	3.5833	3.566	3.4167	0.019	0.009	3.6040	3.5833	3.5833	3.4167	3.6500	0.022	3.3713	0.1336
43	3.5833	3.1033	3.6667	3.650	3.5000	0.019	0.009	3.6873	3.6667	3.6667	3.5000	3.7333	0.022	3.4523	0.1336
44	3.6667	3.1754	3.7500	3.733	3.5833	0.019	0.009	3.7707	3.7500	3.7500	3.5833	3.8167	0.022	3.5380	0.1336
45	3.7500	3.2476	3.8333	3.816	3.6667	0.019	0.009	3.8540	3.8333	3.8333	3.6667	3.9000	0.022	3.6190	0.1336
46	3.8333	3.3198	3.9167	3.900	3.7500	0.019	0.009	3.9373	3.9167	3.9167	3.7500	3.9833	0.022	3.7047	0.1336
47	3.9167	3.3919	4.0000	3.983	3.8333	0.019	0.009	4.0207	4.0000	4.0000	3.8333	4.0667	0.022	3.7858	0.1336
48	4.0000	3.4641	4.0833	4.066	3.9167	0.019	0.009	4.1040	4.0833	4.0833	3.9167	4.1500	0.022	3.8714	0.1336
49	4.0833	3.5363	4.1667	4.150	4.0000	0.019	0.009	4.1873	4.1667	4.1667	4.0000	4.2333	0.022	3.9528	0.1337
50	4.1667	3.6084	4.2500	4.233	4.0833	0.019	0.009	4.2707	4.2500	4.2500	4.0833	4.3167	0.022	4.0382	0.1337

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] $L = 0.0001 \times$ diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 13b—*12/24 Diametral Pitch, External*[a]

12/24 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0417 Dedendum (See Sec 6)	Circular Pitch, 0.2618 Meas-Pin Diam, 0.1600

EXTERNAL

	Major-diameter fit[b]								Fillet root[c]			Dimensions for all fits						
						Flat-root side fit									Tooth thickness			
N	Major diameter			Major-diam chamfer		Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.1304	0.1320	0.1339
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J^e)	+0.0000 −(0.0006 + J^e)	+0.0009 + J^e −0.0000	App	Min	+0.0000 −0.0133	App	Max	+0.0000 −0.0050	+0.0000 −0.0133	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.5818	0.5832	0.5842	0.019	0.008	0.3960	0.014	0.014	0.5833	0.3500	—	0.4430	0.7342	0.7363	0.7388	0.1274	0.1290	0.1309
7	0.6652	0.6666	0.6676	0.019	0.008	0.4793	0.013	0.013	0.6667	0.4333	—	0.5152	0.8022	0.8043	0.8068	0.1274	0.1290	0.1309
8	0.7485	0.7499	0.7509	0.019	0.008	0.5627	0.012	0.011	0.7500	0.5167	0.031	0.5833	0.9031	0.9053	0.9079	0.1274	0.1290	0.1309
9	0.8318	0.8332	0.8342	0.019	0.008	0.6460	0.011	0.011	0.8333	0.6000	0.030	0.6667	0.9747	0.9769	0.9795	0.1274	0.1290	0.1309
10	0.9152	0.9166	0.9176	0.019	0.008	0.7293	0.010	0.010	0.9167	0.6833	0.030	0.7500	1.0711	1.0734	1.0761	0.1273	0.1289	0.1308
11	0.9985	0.9999	1.0009	0.020	0.008	0.8127	0.010	0.009	1.0000	0.7667	0.029	0.8333	1.1449	1.1472	1.1499	0.1273	0.1289	0.1308
12	1.0818	1.0832	1.0842	0.020	0.008	0.8960	0.009	0.009	1.0833	0.8500	0.029	0.9167	1.2389	1.2412	1.2440	0.1273	0.1289	0.1308
13	1.1652	1.1666	1.1676	0.020	0.008	0.9793	0.009	0.009	1.1667	0.9333	0.028	1.0000	1.3143	1.3166	1.3194	0.1273	0.1289	0.1308
14	1.2485	1.2499	1.2509	0.020	0.008	1.0627	0.009	0.008	1.2500	1.0167	0.028	1.0833	1.4065	1.4089	1.4117	0.1273	0.1289	0.1308
15	1.3318	1.3332	1.3342	0.020	0.009	1.1460	0.009	0.008	1.3333	1.1000	0.028	1.1667	1.4829	1.4853	1.4881	0.1273	0.1289	0.1308
16	1.4152	1.4166	1.4176	0.020	0.009	1.2293	0.008	0.008	1.4167	1.1833	0.028	1.2500	1.5738	1.5762	1.5791	0.1273	0.1289	0.1308
17	1.4985	1.4999	1.5010	0.020	0.009	1.3127	0.008	0.008	1.5000	1.2667	0.027	1.3333	1.6511	1.6535	1.6564	0.1273	0.1289	0.1308
18	1.5818	1.5832	1.5843	0.020	0.009	1.3960	0.008	0.007	1.5833	1.3500	0.027	1.4167	1.7411	1.7435	1.7463	0.1273	0.1289	0.1308
19	1.6652	1.6666	1.6677	0.020	0.009	1.4793	0.008	0.007	1.6667	1.4333	0.027	1.5000	1.8191	1.8215	1.8243	0.1273	0.1289	0.1308
20	1.7485	1.7499	1.7510	0.020	0.009	1.5627	0.008	0.007	1.7500	1.5167	0.027	1.5833	1.9082	1.9107	1.9135	0.1273	0.1289	0.1308
21	1.8318	1.8332	1.8343	0.020	0.009	1.6460	0.008	0.007	1.8333	1.6000	0.027	1.6667	1.9867	1.9891	1.9920	0.1273	0.1289	0.1308
22	1.9152	1.9166	1.9177	0.020	0.009	1.7293	0.008	0.007	1.9167	1.6833	0.027	1.7500	2.0754	2.0778	2.0807	0.1273	0.1289	0.1308
23	1.9985	1.9999	2.0010	0.020	0.009	1.8127	0.008	0.007	2.0000	1.7667	0.027	1.8333	2.1542	2.1566	2.1595	0.1273	0.1289	0.1308
24	2.0818	2.0832	2.0843	0.020	0.009	1.8960	0.008	0.007	2.0833	1.8500	0.026	1.9167	2.2423	2.2448	2.2477	0.1273	0.1289	0.1308
25	2.1652	2.1666	2.1677	0.020	0.009	1.9793	0.008	0.007	2.1667	1.9333	0.026	2.0000	2.3216	2.3241	2.3270	0.1273	0.1289	0.1308
26	2.2485	2.2499	2.2510	0.020	0.009	2.0627	0.008	0.007	2.2500	2.0167	0.026	2.0833	2.4093	2.4118	2.4147	0.1273	0.1289	0.1308
27	2.3318	2.3332	2.3343	0.020	0.009	2.1460	0.008	0.006	2.3333	2.1000	0.026	2.1667	2.4889	2.4914	2.4943	0.1273	0.1289	0.1308
28	2.4152	2.4166	2.4177	0.020	0.009	2.2293	0.008	0.006	2.4167	2.1833	0.026	2.2500	2.5761	2.5786	2.5816	0.1272	0.1288	0.1307
29	2.4985	2.4999	2.5011	0.020	0.009	2.3127	0.008	0.006	2.5000	2.2667	0.026	2.3333	2.6559	2.6584	2.6614	0.1272	0.1288	0.1307
30	2.5818	2.5832	2.5844	0.020	0.009	2.3960	0.008	0.006	2.5833	2.3500	0.026	2.4167	2.7431	2.7456	2.7486	0.1272	0.1288	0.1307
31	2.6652	2.6666	2.6678	0.020	0.009	2.4793	0.008	0.006	2.6667	2.4333	0.026	2.5000	2.8231	2.8256	2.8286	0.1272	0.1288	0.1307
32	2.7485	2.7499	2.7511	0.020	0.009	2.5627	0.008	0.006	2.7500	2.5167	0.026	2.5833	2.9099	2.9124	2.9155	0.1272	0.1288	0.1307
33	2.8318	2.8332	2.8344	0.020	0.009	2.6460	0.008	0.006	2.8333	2.6000	0.026	2.6667	2.9901	2.9926	2.9957	0.1272	0.1288	0.1307
34	2.9152	2.9166	2.9178	0.020	0.009	2.7293	0.008	0.006	2.9167	2.6833	0.026	2.7500	3.0767	3.0792	3.0823	0.1272	0.1288	0.1307
35	2.9985	2.9999	3.0011	0.020	0.009	2.8127	0.008	0.006	3.0000	2.7667	0.026	2.8333	3.1571	3.1596	3.1627	0.1272	0.1288	0.1307
36	3.0818	3.0832	3.0844	0.020	0.009	2.8960	0.008	0.006	3.0833	2.8500	0.026	2.9167	3.2436	3.2461	3.2492	0.1272	0.1288	0.1307
37	3.1652	3.1666	3.1678	0.020	0.009	2.9793	0.008	0.006	3.1667	2.9333	0.026	3.0000	3.3242	3.3267	3.3298	0.1272	0.1288	0.1307
38	3.2485	3.2499	3.2511	0.020	0.009	3.0627	0.008	0.006	3.2500	3.0167	0.026	3.0833	3.4104	3.4129	3.4160	0.1272	0.1288	0.1307
39	3.3318	3.3332	3.3344	0.020	0.009	3.1460	0.008	0.006	3.3333	3.1000	0.025	3.1667	3.4911	3.4936	3.4967	0.1272	0.1288	0.1307
40	3.4152	3.4166	3.4178	0.020	0.009	3.2293	0.008	0.006	3.4167	3.1833	0.025	3.2500	3.5772	3.5798	3.5830	0.1272	0.1288	0.1307
41	3.4985	3.4999	3.5012	0.020	0.009	3.3127	0.008	0.006	3.5000	3.2667	0.025	3.3333	3.6580	3.6606	3.6637	0.1272	0.1288	0.1307
42	3.5818	3.5832	3.5845	0.020	0.009	3.3960	0.008	0.006	3.5833	3.3500	0.025	3.4167	3.7440	3.7466	3.7497	0.1272	0.1288	0.1307
43	3.6652	3.6666	3.6679	0.020	0.009	3.4793	0.008	0.006	3.6667	3.4333	0.025	3.5000	3.8249	3.8275	3.8306	0.1272	0.1288	0.1307
44	3.7485	3.7499	3.7512	0.020	0.009	3.5627	0.008	0.006	3.7500	3.5167	0.025	3.5833	3.9108	3.9134	3.9165	0.1272	0.1288	0.1307
45	3.8318	3.8332	3.8345	0.020	0.009	3.6460	0.008	0.006	3.8333	3.6000	0.025	3.6667	3.9918	3.9944	3.9975	0.1272	0.1288	0.1307
46	3.9152	3.9166	3.9179	0.020	0.009	3.7293	0.008	0.006	3.9167	3.6833	0.025	3.7500	4.0776	4.0802	4.0833	0.1272	0.1288	0.1307
47	3.9985	3.9999	4.0012	0.020	0.009	3.8127	0.008	0.006	4.0000	3.7667	0.025	3.8333	4.1585	4.1611	4.1642	0.1271	0.1287	0.1306
48	4.0818	4.0832	4.0845	0.020	0.009	3.8960	0.008	0.006	4.0833	3.8500	0.025	3.9167	4.2441	4.2467	4.2498	0.1271	0.1287	0.1306
49	4.1652	4.1666	4.1679	0.020	0.009	3.9793	0.008	0.006	4.1667	3.9333	0.025	4.0000	4.3254	4.3280	4.3311	0.1271	0.1287	0.1306
50	4.2485	4.2499	4.2512	0.020	0.009	4.0627	0.008	0.005	4.2500	4.0167	0.025	4.0833	4.4109	4.4135	4.4166	0.1271	0.1287	0.1306

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 13a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 14a—*16/32 Diametral Pitch, Internal*[a]

16/32 Diametral Pitch
Pressure Angle, 30°

Addendum (Basic), 0.0313
Dedeadum (See Sec 6)

Circular Pitch, 0.1963
Meas-Pin Diam, 0.0960

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Filet-root side fit			All fits	
					Flat-Root Side Fit									Space width	
						Major-diam fillet		Major diam							
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad	Measurement between pins	Min effective 0.0982
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance→			$+0.0007 + L^d - 0.0000$	Min	$+0.0025 - 0.0000$	App	Max	$+0.0112 - 0.0000$	$+0.0007 + L^d - (0.0007 + L)$	Min	$+0.0025 - 0.0000$	$+0.0112 - 0.0000$	Min[e]	Max	Dimensional Max[f]
6	0.3750	0.3248	0.4375	0.432	0.3348	0.009	0.003	0.4540	0.4375	0.4375	0.3348	0.4875	0.006	0.2792	0.1006
7	0.4375	0.3789	0.5000	0.483	0.3889	0.010	0.004	0.5165	0.5000	0.5000	0.3889	0.5500	0.008	0.3310	0.1007
8	0.5000	0.4330	0.5625	0.555	0.4375	0.011	0.004	0.5790	0.5625	0.5625	0.4375	0.6125	0.009	0.4043	0.1007
9	0.5625	0.4871	0.6250	0.618	0.5000	0.011	0.004	0.6415	0.6250	0.6250	0.5000	0.6750	0.010	0.4584	0.1007
10	0.6250	0.5413	0.6875	0.678	0.5625	0.012	0.005	0.7040	0.6875	0.6875	0.5625	0.7375	0.011	0.5294	0.1007
11	0.6875	0.5954	0.7500	0.741	0.6250	0.012	0.005	0.7665	0.7500	0.7500	0.6250	0.8000	0.012	0.5849	0.1007
12	0.7500	0.6495	0.8125	0.803	0.6875	0.012	0.005	0.8290	0.8125	0.8125	0.6875	0.8625	0.012	0.6543	0.1007
13	0.8125	0.7036	0.8750	0.866	0.7500	0.012	0.005	0.8915	0.8750	0.8750	0.7500	0.9250	0.013	0.7110	0.1007
14	0.8750	0.7578	0.9375	0.928	0.8125	0.012	0.005	0.9540	0.9375	0.9375	0.8125	0.9875	0.013	0.7794	0.1007
15	0.9375	0.8119	1.0000	0.989	0.8750	0.013	0.006	1.0165	1.0000	1.0000	0.8750	1.0500	0.014	0.8368	0.1007
16	1.0000	0.8660	1.0625	1.051	0.9375	0.013	0.006	1.0790	1.0625	1.0625	0.9375	1.1125	0.014	0.9045	0.1007
17	1.0625	0.9202	1.1250	1.114	1.0000	0.013	0.006	1.1415	1.1250	1.1250	1.0000	1.1750	0.014	0.9623	0.1007
18	1.1250	0.9743	1.1875	1.176	1.0625	0.013	0.006	1.2040	1.1875	1.1875	1.0625	1.2375	0.014	1.0294	0.1007
19	1.1875	1.0284	1.2500	1.239	1.1250	0.013	0.006	1.2665	1.2500	1.2500	1.1250	1.3000	0.014	1.0878	0.1007
20	1.2500	1.0825	1.3125	1.301	1.1875	0.013	0.006	1.3290	1.3125	1.3125	1.1875	1.3625	0.014	1.1543	0.1007
21	1.3125	1.1367	1.3750	1.364	1.2500	0.013	0.006	1.3915	1.3750	1.3750	1.2500	1.4250	0.015	1.2134	0.1008
22	1.3750	1.1908	1.4375	1.426	1.3125	0.013	0.006	1.4540	1.4375	1.4375	1.3125	1.4875	0.015	1.2795	0.1008
23	1.4375	1.2449	1.5000	1.489	1.3750	0.013	0.006	1.5165	1.5000	1.5000	1.3750	1.5500	0.015	1.3387	0.1008
24	1.5000	1.2990	1.5625	1.551	1.4375	0.013	0.006	1.5790	1.5625	1.5625	1.4375	1.6125	0.015	1.4045	0.1008
25	1.5625	1.3532	1.6250	1.614	1.5000	0.013	0.006	1.6415	1.6250	1.6250	1.5000	1.6750	0.015	1.4640	0.1008
26	1.6250	1.4073	1.6875	1.676	1.5625	0.013	0.006	1.7040	1.6875	1.6875	1.5625	1.7375	0.015	1.5296	0.1008
27	1.6875	1.4614	1.7500	1.739	1.6250	0.013	0.006	1.7665	1.7500	1.7500	1.6250	1.8000	0.015	1.5892	0.1008
28	1.7500	1.5155	1.8125	1.801	1.6875	0.014	0.006	1.8290	1.8125	1.8125	1.6875	1.8625	0.015	1.6546	0.1008
29	1.8125	1.5697	1.8750	1.864	1.7500	0.014	0.006	1.8915	1.8750	1.8750	1.7500	1.9250	0.015	1.7144	0.1008
30	1.8750	1.6238	1.9375	1.926	1.8125	0.014	0.006	1.9540	1.9375	1.9375	1.8125	1.9875	0.016	1.7796	0.1008
31	1.9375	1.6779	2.0000	1.989	1.8750	0.014	0.006	2.0165	2.0000	2.0000	1.8750	2.0500	0.016	1.8396	0.1008
32	2.0000	1.7321	2.0625	2.051	1.9375	0.014	0.006	2.0790	2.0625	2.0625	1.9375	2.1125	0.016	1.9046	0.1008
33	2.0625	1.7862	2.1250	2.114	2.0000	0.014	0.006	2.1415	2.1250	2.1250	2.0000	2.1750	0.016	1.9648	0.1008
34	2.1250	1.8403	2.1875	2.176	2.0625	0.014	0.006	2.2040	2.1875	2.1875	2.0625	2.2375	0.016	2.0296	0.1008
35	2.1875	1.8944	2.2500	2.237	2.1250	0.014	0.007	2.2665	2.2500	2.2500	2.1250	2.3000	0.016	2.0900	0.1009
36	2.2500	1.9486	2.3125	2.299	2.1875	0.014	0.007	2.3290	2.3125	2.3125	2.1875	2.3625	0.016	2.1547	0.1009
37	2.3125	2.0027	2.3750	2.362	2.2500	0.014	0.007	2.3915	2.3750	2.3750	2.2500	2.4250	0.016	2.2151	0.1009
38	2.3750	2.0568	2.4375	2.424	2.3125	0.014	0.007	2.4540	2.4375	2.4375	2.3125	2.4875	0.016	2.2797	0.1009
39	2.4375	2.1109	2.5000	2.487	2.3750	0.014	0.007	2.5165	2.5000	2.5000	2.3750	2.5500	0.016	2.3402	0.1009
40	2.5000	2.1651	2.5625	2.550	2.4375	0.014	0.007	2.5790	2.5625	2.5625	2.4375	2.6125	0.016	2.4047	0.1009
41	2.5625	2.2192	2.6250	2.612	2.5000	0.014	0.007	2.6415	2.6250	2.6250	2.5000	2.6750	0.016	2.4653	0.1009
42	2.6250	2.2733	2.6875	2.675	2.5625	0.014	0.007	2.7040	2.6875	2.6875	2.5625	2.7375	0.016	2.5297	0.1009
43	2.6875	2.3274	2.7500	2.737	2.6250	0.014	0.007	2.7665	2.7500	2.7500	2.6250	2.8000	0.016	2.5904	0.1009
44	2.7500	2.3816	2.8125	2.800	2.6875	0.014	0.007	2.8290	2.8125	2.8125	2.6875	2.8625	0.016	2.6547	0.1009
45	2.8125	2.4357	2.8750	2.862	2.7500	0.014	0.007	2.8915	2.8750	2.8750	2.7500	2.9250	0.016	2.7154	0.1009
46	2.8750	2.4898	2.9375	2.925	2.8125	0.014	0.007	2.9540	2.9375	2.9375	2.8125	2.9875	0.016	2.7797	0.1009
47	2.9375	2.5440	3.0000	2.987	2.8750	0.014	0.007	3.0165	3.0000	3.0000	2.8750	3.0500	0.016	2.8385	0.1009
48	3.0000	2.5981	3.0625	3.050	2.9375	0.014	0.007	3.0790	3.0625	3.0625	2.9375	3.1125	0.016	2.9047	0.1009
49	3.0625	2.6522	3.1250	3.112	3.0000	0.014	0.007	3.1415	3.1250	3.1250	3.0000	3.1750	0.016	2.9658	0.1010
50	3.1250	2.7063	3.1875	3.175	3.0625	0.014	0.007	3.2040	3.1875	3.1875	3.0625	3.2375	0.016	3.0299	0.1010

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] $L = 0.0001 \times$ diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 14b—*16/32 Diametral Pitch, External*[a]

16/32 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0313 Dedendum (See Sec 6)	Circular Pitch, 0.1963 Meas-Pin Diam, 0.1200

EXTERNAL

	Major-diameter fit[b]								Fillet root[c]			Dimensions for all fits					
						Flat-root side fit									Tooth thickness		
N	Major diameter			Major-diam chamfer		Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.0977	0.0993	0.1012
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J[e])	+0.0000 −(0.0096 + J[e])	+0.0009 + J[e] −0.0000	App	Min	+0.0000 −0.0112	App	Max	+0.0000 −0.0050	+0.0000 −0.0112	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.4360	0.4374	0.4383	0.014	0.006	0.2960	0.011	0.011	0.4375	0.2500	—	0.3348	0.5495	0.5516	0.5541	0.0947	0.0963	0.0982
7	0.4985	0.4999	0.5009	0.014	0.006	0.3585	0.009	0.009	0.5000	0.3125	—	0.3889	0.6005	0.6026	0.6051	0.0947	0.0963	0.0982
8	0.5610	0.5624	0.5634	0.014	0.006	0.4210	0.009	0.009	0.5625	0.3750	—	0.4375	0.6761	0.6783	0.6809	0.0947	0.0963	0.0982
9	0.6235	0.6249	0.6259	0.015	0.006	0.4835	0.008	0.008	0.6250	0.4375	—	0.5000	0.7298	0.7320	0.7346	0.0947	0.0963	0.0982
10	0.6860	0.6874	0.6884	0.015	0.006	0.5460	0.008	0.007	0.6875	0.5000	—	0.5625	0.8021	0.8044	0.8071	0.0946	0.0962	0.0981
11	0.7485	0.7499	0.7509	0.015	0.006	0.6085	0.007	0.007	0.7500	0.5625	—	0.6250	0.8574	0.8597	0.8624	0.0946	0.0962	0.0981
12	0.8110	0.8124	0.8134	0.015	0.006	0.6710	0.007	0.007	0.8125	0.6250	0.020	0.6875	0.9279	0.9302	0.9330	0.0946	0.0962	0.0981
13	0.8735	0.8749	0.8759	0.015	0.006	0.7335	0.007	0.006	0.8750	0.6875	0.019	0.7500	0.9844	0.9876	0.9895	0.0946	0.0962	0.0981
14	0.9360	0.9374	0.9384	0.015	0.006	0.7960	0.007	0.006	0.9375	0.7500	0.019	0.8125	1.0535	1.0559	1.0587	0.0946	0.0962	0.0981
15	0.9985	0.9999	1.0009	0.015	0.006	0.8585	0.006	0.006	1.0000	0.8125	0.018	0.8750	1.1109	1.1132	1.1161	0.0946	0.0962	0.0981
16	1.0610	1.0624	1.0634	0.015	0.006	0.9210	0.006	0.006	1.0625	0.8750	0.018	0.9375	1.1790	1.1814	1.1843	0.0946	0.0962	0.0981
17	1.1235	1.1249	1.1259	0.015	0.006	0.9835	0.006	0.006	1.1250	0.9375	0.018	1.0000	1.2370	1.2394	1.2423	0.0946	0.0962	0.0981
18	1.1860	1.1874	1.1884	0.015	0.006	1.0460	0.006	0.006	1.1875	1.0000	0.018	1.0625	1.3045	1.3069	1.3097	0.0946	0.0962	0.0981
19	1.2485	1.2499	1.2509	0.015	0.006	1.1085	0.006	0.005	1.2500	1.0625	0.017	1.1250	1.3629	1.3653	1.3681	0.0946	0.0962	0.0981
20	1.3110	1.3124	1.3134	0.015	0.007	1.1710	0.006	0.005	1.3125	1.1250	0.017	1.1875	1.4298	1.4323	1.4351	0.0946	0.0962	0.0981
21	1.3735	1.3749	1.3759	0.015	0.007	1.2335	0.006	0.005	1.3750	1.1875	0.017	1.2500	1.4886	1.4910	1.4939	0.0946	0.0962	0.0981
22	1.4360	1.4374	1.4384	0.015	0.007	1.2960	0.006	0.005	1.4375	1.2500	0.017	1.3125	1.5552	1.5576	1.5605	0.0946	0.0962	0.0981
23	1.4985	1.4999	1.5010	0.015	0.007	1.3585	0.006	0.005	1.5000	1.3125	0.017	1.3750	1.6143	1.6167	1.6196	0.0946	0.0962	0.0981
24	1.5610	1.5624	1.5635	0.015	0.007	1.4210	0.006	0.005	1.5625	1.3750	0.016	1.4375	1.6804	1.6829	1.6858	0.0946	0.0962	0.0981
25	1.6235	1.6249	1.6260	0.015	0.007	1.4835	0.006	0.005	1.6250	1.4375	0.016	1.5000	1.7398	1.7423	1.7452	0.0946	0.0962	0.0981
26	1.6860	1.6874	1.6885	0.015	0.007	1.5460	0.006	0.005	1.6875	1.5000	0.016	1.5625	1.8056	1.8081	1.8110	0.0946	9.0962	0.0981
27	1.7485	1.7499	1.7510	0.015	0.007	1.6085	0.006	0.005	1.7500	1.5625	0.016	1.6250	1.8653	1.8678	1.8707	0.0946	0.0962	0.0981
28	1.8110	1.8124	1.8135	0.015	0.007	1.6710	0.006	0.005	1.8125	1.6250	0.016	1.6875	1.9306	1.9331	1.9361	0.0945	0.0961	0.0980
29	1.8735	1.8749	1.8760	0.015	0.007	1.7335	0.006	0.005	1.8750	1.6875	0.016	1.7500	1.9905	1.9930	1.9960	0.0945	0.0961	0.0980
30	1.9360	1.9374	1.9385	0.015	0.007	1.7960	0.006	0.005	1.9375	1.7500	0.016	1.8125	2.0558	2.0583	2.0613	0.0945	0.0961	0.0980
31	1.9985	1.9999	2.0010	0.015	0.007	1.8585	0.006	0.005	2.0000	1.8125	0.016	1.8750	2.1159	2.1184	2.1214	0.0945	0.0961	0.0980
32	2.0610	2.0624	2.0635	0.015	0.007	1.9210	0.006	0.005	2.0625	1.8750	0.015	1.9375	2.1809	2.1834	2.1865	0.0945	0.0961	0.0980
33	2.1235	2.1249	2.1260	0.015	0.007	1.9835	0.006	0.005	2.1250	1.9375	0.015	2.0000	2.2411	2.2436	2.2467	0.0945	0.0961	0.0980
34	2.1860	2.1874	2.1885	0.015	0.007	2.0460	0.006	0.005	2.1875	2.0000	0.015	2.0625	2.3061	2.3086	2.3117	0.0945	0.0961	0.0980
35	2.2485	2.2499	2.2510	0.015	0.007	2.1085	0.006	0.004	2.2500	2.0625	0.015	2.1250	2.3664	2.3689	2.3720	0.0945	0.0961	0.0980
36	2.3110	2.3124	2.3135	0.015	0.007	2.1710	0.006	0.004	2.3125	2.1250	0.015	2.1875	2.4312	2.4337	2.4368	0.0945	0.0961	0.0980
37	2.3735	2.3749	2.3760	0.015	0.007	2.2335	0.006	0.004	2.3750	2.1875	0.015	2.2500	2.4916	2.4941	2.4972	0.0945	0.0961	0.0980
38	2.4360	2.4374	2.4385	0.015	0.007	2.2960	0.006	0.004	2.4375	2.2500	0.015	2.3125	2.5564	2.5589	2.5620	0.0945	0.0961	0.0980
39	2.4985	2.4999	2.5011	0.015	0.007	2.3585	0.006	0.004	2.5000	2.3125	0.015	2.3750	2.6169	2.6194	2.6225	0.0945	0.0961	0.0980
40	2.5610	2.5624	2.5636	0.015	0.007	2.4210	0.006	0.004	2.5625	2.3750	0.015	2.4375	2.6814	2.6840	2.6871	0.0945	0.0961	0.0980
41	2.6235	2.6249	2.6261	0.015	0.007	2.4835	0.006	0.004	2.6250	2.4375	0.015	2.5000	2.7420	2.7446	2.7477	0.0945	0.0961	0.0980
42	2.6860	2.6874	2.6886	0.015	0.007	2.5460	0.006	0.004	2.6875	2.5000	0.015	2.5625	2.8065	2.8091	2.8122	0.0945	0.0961	0.0980
43	2.7485	2.7499	2.7511	0.015	0.007	2.6085	0.006	0.004	2.7500	2.5625	0.015	2.6250	2.8672	2.8698	2.8729	0.0945	0.0961	0.0980
44	2.8110	2.8124	2.8136	0.015	0.007	2.6710	0.006	0.004	2.8125	2.6250	0.015	2.6875	2.9316	2.9342	2.9373	0.0945	0.0961	0.0980
45	2.8735	2.8749	2.8761	0.015	0.007	2.7335	0.006	0.004	2.8750	2.6875	0.015	2.7500	2.9924	2.9950	2.9981	0.0945	0.0961	0.0980
46	2.9360	2.9374	2.9386	0.015	0.007	2.7960	0.006	0.004	2.9375	2.7500	0.015	2.8125	3.0567	3.0593	3.0624	0.0945	0.0961	0.0980
47	2.9985	2.9999	3.0011	0.015	0.007	2.8585	0.006	0.004	3.0000	2.8125	0.015	2.8750	3.1173	3.1199	3.1230	0.0944	0.0960	0.0979
48	3.0610	3.0624	3.0636	0.015	0.007	2.9210	0.006	0.004	3.0625	2.8750	0.014	2.9375	3.1816	3.1842	3.1873	0.0944	0.0960	0.0979
49	3.1235	3.1249	3.1261	0.015	0.007	2.9835	0.006	0.004	3.1250	2.9375	0.014	3.0000	3.2425	3.2451	3.2482	0.0944	0.0960	0.0979
50	3.1860	3.1874	3.1886	0.015	0.007	3.0460	0.006	0.004	3.1875	3.0000	0.014	3.0625	3.3066	3.3092	3.3123	0.0944	0.0960	0.0979

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 14a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 15a—*20/40 Diametral Pitch, Internal*[a]

20/40 Diametral Pitch
Pressure Angle, 30°

Addendum (Basic), 0.0250
Dedendum (See Sec 6)

Circular Pitch, 0.1571
Meas-Pin Diam, 0.0720

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits	
					Flat-Root Side Fit										
						Major-diam fillet		Major diam							Space width
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad	Measurement between pins	Min effective 0.0785
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance→			$+0.0007$ $+ L^d$ -0.0000	Min	$+0.0025$ -0.0000	App	Max	$+0.0100$ -0.0000	$+0.0007$ $+ L^d$ $-(0.0007$ $+ L)$	Min	$+0.0025$ -0.0000	$+0.0100$ -0.0000	Min[e]	Max	Dimensional Max[f]
6	0.3000	0.2598	0.3500	0.345	0.2698	0.007	0.003	0.3640	0.3500	0.3500	0.2698	0.3900	0.003	0.2243	0.0809
7	0.3500	0.3031	0.4000	0.395	0.3131	0.008	0.003	0.4140	0.4000	0.4000	0.3131	0.4400	0.006	0.2658	0.0810
8	0.4000	0.3464	0.4500	0.445	0.3500	0.008	0.003	0.4640	0.4500	0.4500	0.3500	0.4900	0.007	0.3244	0.0810
9	0.4500	0.3897	0.5000	0.493	0.4000	0.008	0.004	0.5140	0.5000	0.5000	0.4000	0.5400	0.008	0.3676	0.0810
10	0.5000	0.4330	0.5500	0.543	0.4500	0.009	0.004	0.5640	0.5500	0.5500	0.4500	0.5900	0.008	0.4244	0.0810
11	0.5500	0.4763	0.6000	0.593	0.5000	0.009	0.004	0.6140	0.6000	0.6000	0.5000	0.6400	0.009	0.4688	0.0810
12	0.6000	0.5196	0.6500	0.643	0.5500	0.010	0.004	0.6640	0.6500	0.6500	0.5500	0.6900	0.009	0.5244	0.0810
13	0.6500	0.5629	0.7000	0.693	0.6000	0.010	0.004	0.7140	0.7000	0.7000	0.6000	0.7400	0.010	0.5697	0.0810
14	0.7000	0.6062	0.7500	0.743	0.6500	0.010	0.004	0.7640	0.7500	0.7500	0.6500	0.7900	0.010	0.6244	0.0810
15	0.7500	0.6495	0.8000	0.793	0.7000	0.010	0.004	0.8140	0.8000	0.8000	0.7000	0.8400	0.010	0.6703	0.0810
16	0.8000	0.6928	0.8500	0.843	0.7500	0.010	0.004	0.8640	0.8500	0.8500	0.7500	0.8900	0.010	0.7244	0.0810
17	0.8500	0.7361	0.9000	0.891	0.8000	0.010	0.005	0.9140	0.9000	0.9000	0.8000	0.9400	0.011	0.7707	0.0810
18	0.9000	0.7794	0.9500	0.941	0.8500	0.010	0.005	0.9640	0.9500	0.9500	0.8500	0.9900	0.011	0.8244	0.0810
19	0.9500	0.8227	1.0000	0.991	0.9000	0.010	0.005	1.0140	1.0000	1.0000	0.9000	1.0400	0.011	0.8711	0.0810
20	1.0000	0.8660	1.0500	1.041	0.9500	0.010	0.005	1.0640	1.0500	1.0500	0.9500	1.0900	0.011	0.9243	0.0810
21	1.0500	0.9093	1.1000	1.091	1.0000	0.011	0.005	1.1140	1.1000	1.1000	1.0000	1.1400	0.011	0.9716	0.0811
22	1.1000	0.9526	1.1500	1.141	1.0500	0.011	0.005	1.1640	1.1500	1.1500	1.0500	1.1900	0.011	1.0245	0.0811
23	1.1500	0.9959	1.2000	1.191	1.1000	0.011	0.005	1.2140	1.2000	1.2000	1.1000	1.2400	0.011	1.0719	0.0811
24	1.2000	1.0392	1.2500	1.241	1.1500	0.011	0.005	1.2640	1.2500	1.2500	1.1500	1.2900	0.011	1.1245	0.0811
25	1.2500	1.0825	1.3000	1.291	1.2000	0.011	0.005	1.3140	1.3000	1.3000	1.2000	1.3400	0.012	1.1721	0.0811
26	1.3000	1.1258	1.3500	1.341	1.2500	0.011	0.005	1.3640	1.3500	1.3500	1.2500	1.3900	0.012	1.2246	0.0811
27	1.3500	1.1691	1.4000	1.391	1.3000	0.011	0.005	1.4140	1.4000	1.4000	1.3000	1.4400	0.012	1.2723	0.0811
28	1.4000	1.2124	1.4500	1.441	1.3500	0.011	0.005	1.4640	1.4500	1.4500	1.3500	1.4900	0.012	1.3246	0.0811
29	1.4500	1.2557	1.5000	1.491	1.4000	0.011	0.005	1.5140	1.5000	1.5000	1.4000	1.5400	0.012	1.3725	0.0811
30	1.5000	1.2990	1.5500	1.541	1.4500	0.011	0.005	1.5640	1.5500	1.5500	1.4500	1.5900	0.012	1.4246	0.0811
31	1.5500	1.3423	1.6000	1.591	1.5000	0.011	0.005	1.6140	1.6000	1.6000	1.5000	1.6400	0.012	1.4726	0.0811
32	1.6000	1.3856	1.6500	1.641	1.5500	0.011	0.005	1.6640	1.6500	1.6500	1.5500	1.6900	0.012	1.5246	0.0811
33	1.6500	1.4289	1.7000	1.691	1.6000	0.011	0.005	1.7140	1.7000	1.7000	1.6000	1.7400	0.012	1.5727	0.0811
34	1.7000	1.4722	1.7500	1.741	1.6500	0.011	0.005	1.7640	1.7500	1.7500	1.6500	1.7900	0.012	1.6246	0.0811
35	1.7500	1.5155	1.8000	1.791	1.7000	0.011	0.005	1.8140	1.8000	1.8000	1.7000	1.8400	0.012	1.6729	0.0812
36	1.8000	1.5588	1.8500	1.841	1.7500	0.011	0.005	1.8640	1.8500	1.8500	1.7500	1.8900	0.012	1.7247	0.0812
37	1.8500	1.6021	1.9000	1.891	1.8000	0.011	0.005	1.9140	1.9000	1.9000	1.8000	1.9400	0.012	1.7730	0.0812
38	1.9000	1.6454	1.9500	1.941	1.8500	0.011	0.005	1.9640	1.9500	1.9500	1.8500	1.9900	0.012	1.8247	0.0812
39	1.9500	1.6887	2.0000	1.991	1.9000	0.011	0.005	2.0140	2.0000	2.0000	1.9000	2.0400	0.012	1.8731	0.0812
40	2.0000	1.7321	2.0500	2.041	1.9500	0.011	0.005	2.0640	2.0500	2.0500	1.9500	2.0900	0.012	1.9247	0.0812
41	2.0500	1.7754	2.1000	2.091	2.0000	0.011	0.005	2.1140	2.1000	2.1000	2.0000	2.1400	0.012	1.9732	0.0812
42	2.1000	1.8187	2.1500	2.141	2.0500	0.011	0.005	2.1640	2.1500	2.1500	2.0500	2.1900	0.012	2.0247	0.0812
43	2.1500	1.8620	2.2000	2.191	2.1000	0.011	0.005	2.2140	2.2000	2.2000	2.1000	2.2400	0.012	2.0732	0.0812
44	2.2000	1.9053	2.2500	2.241	2.1500	0.011	0.005	2.2640	2.2500	2.2500	2.1500	2.2900	0.012	2.1247	0.0812
45	2.2500	1.9486	2.3000	2.291	2.2000	0.011	0.005	2.3140	2.3000	2.3000	2.2000	2.3400	0.012	2.1733	0.0812
46	2.3000	1.9919	2.3500	2.341	2.2500	0.011	0.005	2.3640	2.3500	2.3500	2.2500	2.3900	0.013	2.2247	0.0812
47	2.3500	2.0352	2.4000	2.391	2.3000	0.011	0.005	2.4140	2.4000	2.4000	2.3000	2.4400	0.013	2.2734	0.0812
48	2.4000	2.0785	2.4500	2.441	2.3500	0.011	0.005	2.4640	2.4500	2.4500	2.3500	2.4900	0.013	2.3247	0.0812
49	2.4500	2.1218	2.5000	2.491	2.4000	0.011	0.005	2.5140	2.5000	2.5000	2.4000	2.5400	0.013	2.3736	0.0813
50	2.5000	2.1651	2.5500	2.541	2.4500	0.011	0.005	2.5640	2.5500	2.5500	2.4500	2.5900	0.013	2.4249	0.0814

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generat ng process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] $L = 0.0001 \times$ diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 15b—*20/40 Diametral Pitch, External*[a]

20/40 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0250 Dedendum (See Sec 6)	Circular Pitch, 0.1571 Meas-Pin Diam, 0.0960

EXTERNAL

	Major-diameter fit[b]					Fillet root[c]			Dimensions for all fits									
						Flat-root side fit									Tooth thickness			
	Major diameter			Major-diam chamfer		Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
N	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.0780	0.0796	0.0815
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J^e)	+0.0000 −(0.0006 + J^e)	+0.0009 + J^e −0.0000	App	Min	+0.0000 −0.0100	App	Max	+0.0000 −0.0050	+0.0000 −0.0100	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.3485	0.3499	0.3508	0.011	0.005	0.2360	0.009	0.008	0.3500	0.2000	—	0.2698	0.4387	0.4408	0.4433	0.0750	0.0766	0.0785
7	0.3985	0.3999	0.4008	0.012	0.005	0.2860	0.008	0.008	0.4000	0.2500	—	0.3131	0.4795	0.4816	0.4841	0.0750	0.0766	0.0785
8	0.4485	0.4499	0.4508	0.012	0.005	0.3360	0.007	0.007	0.4500	0.3000	—	0.3500	0.5398	0.5421	0.5447	0.0750	0.0766	0.0785
9	0.4985	0.4999	0.5009	0.012	0.005	0.3860	0.007	0.006	0.5000	0.3500	—	0.4000	0.5829	0.5851	0.5877	0.0750	0.0766	0.0785
10	0.5485	0.5499	0.5509	0.012	0.005	0.4360	0.006	0.006	0.5500	0.4000	—	0.4500	0.6406	0.6429	0.6456	0.0749	0.0765	0.0784
11	0.5985	0.5999	0.6009	0.012	0.005	0.4860	0.006	0.006	0.6000	0.4500	0.016	0.5000	0.6849	0.6872	0.6899	0.0749	0.0765	0.0784
12	0.6485	0.6499	0.6509	0.012	0.005	0.5360	0.006	0.005	0.6500	0.5000	0.016	0.5500	0.7413	0.7436	0.7464	0.0749	0.0765	0.0784
13	0.6985	0.6999	0.7009	0.012	0.005	0.5860	0.005	0.005	0.7000	0.5500	0.015	0.6000	0.7865	0.7888	0.7916	0.0749	0.0765	0.0784
14	0.7485	0.7499	0.7509	0.012	0.005	0.6360	0.005	0.005	0.7500	0.6000	0.015	0.6500	0.8418	0.8442	0.8470	0.0749	0.0765	0.0784
15	0.7985	0.7999	0.8009	0.012	0.005	0.6860	0.005	0.005	0.8000	0.6500	0.014	0.7000	0.8876	0.8900	0.8928	0.0749	0.0765	0.0784
16	0.8485	0.8499	0.8509	0.012	0.005	0.7360	0.005	0.005	0.8500	0.7000	0.014	0.7500	0.9421	0.9445	0.9474	0.0749	0.0765	0.0784
17	0.8985	0.8999	0.9009	0.012	0.005	0.7860	0.005	0.005	0.9000	0.7500	0.014	0.8000	0.9885	0.9909	0.9938	0.0749	0.0765	0.0784
18	0.9485	0.9499	0.9509	0.012	0.005	0.8360	0.005	0.004	0.9500	0.8000	0.014	0.8500	1.0425	1.0449	1.0477	0.0749	0.0765	0.0784
19	0.9985	0.9999	1.0009	0.012	0.005	0.8860	0.005	0.004	1.0000	0.8500	0.014	0.9000	1.0893	1.0917	1.0945	0.0749	0.0765	0.0784
20	1.0485	1.0499	1.0509	0.012	0.005	0.9360	0.005	0.004	1.0500	0.9000	0.013	0.9500	1.1427	1.1452	1.1480	0.0749	0.0765	0.0784
21	1.0985	1.0999	1.1009	0.012	0.005	0.9860	0.005	0.004	1.1000	0.9500	0.013	1.0000	1.1898	1.1922	1.1951	0.0749	0.0765	0.0784
22	1.1485	1.1499	1.1509	0.012	0.005	1.0360	0.005	0.004	1.1500	1.0000	0.013	1.0500	1.2430	1.2454	1.2483	0.0749	0.0765	0.0784
23	1.1985	1.1999	1.2009	0.012	0.005	1.0860	0.005	0.004	1.2000	1.0500	0.013	1.1000	1.2903	1.2927	1.2956	0.0749	0.0765	0.0784
24	1.2485	1.2499	1.2509	0.012	0.005	1.1360	0.005	0.004	1.2500	1.1000	0.013	1.1500	1.3432	1.3457	1.3486	0.0749	0.0765	0.0784
25	1.2985	1.2999	1.3009	0.012	0.005	1.1860	0.005	0.004	1.3000	1.1500	0.013	1.2000	1.3907	1.3932	1.3961	0.0749	0.0765	0.0784
26	1.3485	1.3499	1.3509	0.012	0.005	1.2360	0.005	0.004	1.3500	1.2000	0.013	1.2500	1.4434	1.4459	1.4488	0.0749	0.0765	0.0784
27	1.3985	1.3999	1.4009	0.012	0.005	1.2860	0.005	0.004	1.4000	1.2500	0.012	1.3000	1.4911	1.4936	1.4965	0.0749	0.0765	0.0784
28	1.4485	1.4499	1.4509	0.012	0.005	1.3360	0.005	0.004	1.4500	1.3000	0.012	1.3500	1.5433	1.5458	1.5488	0.0748	0.0764	0.0783
29	1.4985	1.4999	1.5010	0.012	0.005	1.3860	0.005	0.004	1.5000	1.3500	0.012	1.4000	1.5912	1.5937	1.5967	0.0748	0.0764	0.0783
30	1.5485	1.5499	1.5510	0.012	0.005	1.4360	0.005	0.004	1.5500	1.4000	0.012	1.4500	1.6435	1.6460	1.6490	0.0748	0.0764	0.0783
31	1.5985	1.5999	1.6010	0.012	0.005	1.4860	0.005	0.004	1.6000	1.4500	0.012	1.5000	1.6915	1.6940	1.6970	0.0748	0.0764	0.0783
32	1.6485	1.6499	1.6510	0.012	0.005	1.5360	0.005	0.004	1.6500	1.5000	0.012	1.5500	1.7436	1.7461	1.7492	0.0748	0.0764	0.0783
33	1.6985	1.6999	1.7010	0.012	0.005	1.5860	0.005	0.004	1.7000	1.5500	0.012	1.6000	1.7917	1.7942	1.7973	0.0748	0.0764	0.0783
34	1.7485	1.7499	1.7510	0.012	0.005	1.6360	0.005	0.004	1.7500	1.6000	0.012	1.6500	1.8437	1.8462	1.8493	0.0748	0.0764	0.0783
35	1.7985	1.7999	1.8010	0.012	0.005	1.6860	0.005	0.004	1.8000	1.6500	0.012	1.7000	1.8919	1.8944	1.8975	0.0748	0.0764	0.0783
36	1.8485	1.8499	1.8510	0.012	0.005	1.7360	0.005	0.004	1.8500	1.7000	0.012	1.7500	1.9438	1.9463	1.9494	0.0748	0.0764	0.0783
37	1.8985	1.8999	1.9010	0.012	0.005	1.7860	0.005	0.004	1.9000	1.7500	0.012	1.8000	1.9921	1.9946	1.9977	0.0748	0.0764	0.0783
38	1.9485	1.9499	1.9510	0.012	0.005	1.8360	0.005	0.004	1.9500	1.8000	0.012	1.8500	2.0439	2.0464	2.0495	0.0748	0.0764	0.0783
39	1.9985	1.9999	2.0010	0.012	0.005	1.8860	0.005	0.003	2.0000	1.8500	0.012	1.9000	2.0923	2.0948	2.0979	0.0748	0.0764	0.0783
40	2.0485	2.0499	2.0510	0.012	0.005	1.9360	0.005	0.003	2.0500	1.9000	0.012	1.9500	2.1439	2.1465	2.1496	0.0748	0.0764	0.0783
41	2.0985	2.0999	2.1010	0.012	0.005	1.9860	0.005	0.003	2.1000	1.9500	0.012	2.0000	2.1924	2.1950	2.1981	0.0748	0.0764	0.0783
42	2.1485	2.1499	2.1510	0.012	0.005	2.0360	0.005	0.003	2.1500	2.0000	0.012	2.0500	2.2440	2.2466	2.2497	0.0748	0.0764	0.0783
43	2.1985	2.1999	2.2010	0.012	0.005	2.0860	0.005	0.003	2.2000	2.0500	0.012	2.1000	2.2926	2.2952	2.2983	0.0748	0.0764	0.0783
44	2.2485	2.2499	2.2510	0.012	0.005	2.1360	0.005	0.003	2.2500	2.1000	0.012	2.1500	2.3441	2.3467	2.3498	0.0748	0.0764	0.0783
45	2.2985	2.2999	2.3010	0.012	0.005	2.1860	0.005	0.003	2.3000	2.1500	0.011	2.2000	2.3927	2.3953	2.3984	0.0748	0.0764	0.0783
46	2.3485	2.3499	2.3510	0.012	0.005	2.2360	0.005	0.003	2.3500	2.2000	0.011	2.2500	2.4441	2.4467	2.4498	0.0748	0.0764	0.0783
47	2.3985	2.3999	2.4010	0.012	0.005	2.2860	0.005	0.003	2.4000	2.2500	0.011	2.3000	2.4926	2.4952	2.4983	0.0747	0.0763	0.0782
48	2.4485	2.4499	2.4510	0.012	0.005	2.3360	0.005	0.003	2.4500	2.3000	0.011	2.2500	2.5440	2.5466	2.5497	0.0747	0.0763	0.0782
49	2.4985	2.4999	2.5011	0.012	0.005	2.3860	0.005	0.003	2.5000	2.3500	0.011	2.4000	2.5928	2.5954	2.5985	0.0747	0.0763	0.0782
50	2.5485	2.5499	2.5511	0.012	0.005	2.4360	0.005	0.003	2.5500	2.4000	0.011	2.4500	2.6441	2.6467	2.6498	0.0747	0.0763	0.0782

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 15a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, substract 60% of the lead error from this dimension (see Table 27).

TABLE 16a—*24/48 Diametral Pitch, Internal*[a]

24/48 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0208 Dedendum (See Sec 6)	Circular Pitch, 0.1309 Meas-Pin Diam, 0.0690

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits	
					Flat-Root Side Fit										
						Major-diam fillet		Major diam						Measurement between pins	Space width
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad		Min effective 0.0654
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance⟶			$+0.0007 + L^d$ -0.0000	Min	$+0.0015$ -0.0000	App	Max	$+0.0091$ -0.0000	$+0.0007 + L^d$ $-(0.0007 + L)$	Min	$+0.0015$ -0.0000	$+0.0091$ -0.0000	Min[e]	Max	Dimensional Max[f]
6	0.2500	0.2165	0.2917	0.288	0.2249	0.006	0.002	0.3040	0.2917	0.2917	0.2249	0.3250	—	0.1877	0.0678
7	0.2917	0.2526	0.3333	0.328	0.2624	0.007	0.003	0.3457	0.3333	0.3333	0.2624	0.3667	—	0.2222	0.0679
8	0.3333	0.2887	0.3750	0.370	0.2917	0.007	0.003	0.3873	0.3750	0.3750	0.2917	0.4083	—	0.2711	0.0679
9	0.3750	0.3248	0.4167	0.411	0.3333	0.007	0.003	0.4290	0.4167	0.4167	0.3333	0.4500	0.006	0.3071	0.0679
10	0.4167	0.3608	0.4583	0.453	0.3750	0.008	0.003	0.4707	0.4583	0.4583	0.3750	0.4917	0.006	0.3545	0.0679
11	0.4583	0.3969	0.5000	0.495	0.4167	0.008	0.003	0.5123	0.5000	0.5000	0.4167	0.5333	0.007	0.3914	0.0679
12	0.5000	0.4330	0.5417	0.537	0.4583	0.008	0.003	0.5540	0.5417	0.5417	0.4583	0.5750	0.007	0.4377	0.0679
13	0.5417	0.4691	0.5833	0.576	0.5000	0.008	0.004	0.5957	0.5833	0.5833	0.5000	0.6167	0.007	0.4755	0.0679
14	0.5833	0.5052	0.6250	0.618	0.5417	0.008	0.004	0.6373	0.6250	0.6250	0.5417	0.6583	0.008	0.5211	0.0679
15	0.6250	0.5413	0.6667	0.660	0.5833	0.008	0.004	0.6790	0.6667	0.6667	0.5833	0.7000	0.008	0.5594	0.0679
16	0.6667	0.5774	0.7083	0.701	0.6250	0.008	0.004	0.7207	0.7083	0.7083	0.6250	0.7417	0.008	0.6044	0.0679
17	0.7083	0.6134	0.7500	0.743	0.6667	0.009	0.004	0.7623	0.7500	0.7500	0.6667	0.7833	0.008	0.6430	0.0679
18	0.7500	0.6495	0.7917	0.785	0.7083	0.009	0.004	0.8040	0.7917	0.7917	0.7083	0.8250	0.009	0.6878	0.0679
19	0.7917	0.6856	0.8333	0.826	0.7500	0.009	0.004	0.8457	0.8333	0.8333	0.7500	0.8667	0.009	0.7267	0.0679
20	0.8333	0.7217	0.8750	0.868	0.7917	0.009	0.004	0.8873	0.8750	0.8750	0.7917	0.9083	0.009	0.7710	0.0679
21	0.8750	0.7578	0.9167	0.910	0.8333	0.009	0.004	0.9290	0.9167	0.9167	0.8333	0.9500	0.009	0.8105	0.0680
22	0.9167	0.7939	0.9583	0.951	0.8750	0.009	0.004	0.9707	0.9583	0.9583	0.8750	0.9917	0.009	0.8546	0.0680
23	0.9583	0.8299	1.0000	0.993	0.9167	0.009	0.004	1.0123	1.0000	1.0000	0.9167	1.0333	0.009	0.8940	0.0680
24	1.0000	0.8660	1.0417	1.035	0.9583	0.009	0.004	1.0540	1.0417	1.0417	0.9583	1.0750	0.009	0.9379	0.0680
25	1.0417	0.9021	1.0833	1.076	1.0000	0.009	0.004	1.0957	1.0833	1.0833	1.0000	1.1167	0.009	0.9775	0.0680
26	1.0833	0.9382	1.1250	1.118	1.0417	0.009	0.004	1.1373	1.1250	1.1250	1.0417	1.1583	0.009	1.0212	0.0680
27	1.1250	0.9743	1.1667	1.160	1.0833	0.009	0.004	1.1790	1.1667	1.1667	1.0833	1.2000	0.009	1.0610	0.0680
28	1.1667	1.0104	1.2083	1.201	1.1250	0.009	0.004	1.2207	1.2083	1.2083	1.1250	1.2416	0.009	1.1046	0.0680
29	1.2083	1.0464	1.2500	1.243	1.1667	0.009	0.004	1.2623	1.2500	1.2500	1.1667	1.2833	0.009	1.1445	0.0680
30	1.2500	1.0825	1.2917	1.285	1.2083	0.009	0.004	1.3040	1.2917	1.2917	1.2083	1.3250	0.010	1.1879	0.0680
31	1.2917	1.1186	1.3333	1.326	1.2500	0.009	0.004	1.3457	1.3333	1.3333	1.2500	1.3667	0.010	1.2280	0.0680
32	1.3333	1.1547	1.3750	1.368	1.2917	0.009	0.004	1.3873	1.3750	1.3750	1.2917	1.4083	0.010	1.2712	0.0680
33	1.3750	1.1908	1.4167	1.410	1.3333	0.009	0.004	1.4290	1.4167	1.4167	1.3333	1.4500	0.010	1.3114	0.0680
34	1.4167	1.2269	1.4583	1.451	1.3750	0.009	0.004	1.4707	1.4583	1.4583	1.3750	1.4917	0.010	1.3546	0.0680
35	1.4583	1.2630	1.5000	1.493	1.4167	0.009	0.004	1.5123	1.5000	1.5000	1.4167	1.5333	0.010	1.3949	0.0681
36	1.5000	1.2990	1.5417	1.535	1.4583	0.009	0.004	1.5540	1.5417	1.5417	1.4583	1.5750	0.010	1.4380	0.0681
37	1.5417	1.3351	1.5833	1.576	1.5000	0.009	0.004	1.5957	1.5833	1.5833	1.5000	1.6167	0.010	1.4783	0.0681
38	1.5833	1.3712	1.6250	1.618	1.5417	0.009	0.004	1.6373	1.6250	1.6250	1.5417	1.6583	0.010	1.5213	0.0681
39	1.6250	1.4073	1.6667	1.660	1.5833	0.009	0.004	1.6790	1.6667	1.6667	1.5833	1.7000	0.010	1.5617	0.0681
40	1.6667	1.4434	1.7083	1.701	1.6250	0.009	0.004	1.7207	1.7083	1.7083	1.6250	1.7417	0.010	1.6047	0.0681
41	1.7083	1.4795	1.7500	1.743	1.6667	0.009	0.004	1.7623	1.7500	1.7500	1.6667	1.7833	0.010	1.6451	0.0681
42	1.7500	1.5155	1.7917	1.785	1.7083	0.009	0.004	1.8040	1.7917	1.7917	1.7083	1.8250	0.010	1.6880	0.0681
43	1.7917	1.5516	1.8333	1.826	1.7500	0.009	0.004	1.8457	1.8333	1.8333	1.7500	1.8667	0.010	1.7285	0.0681
44	1.8333	1.5877	1.8750	1.868	1.7917	0.009	0.004	1.8873	1.8750	1.8750	1.7917	1.9083	0.010	1.7714	0.0681
45	1.8750	1.6238	1.9167	1.910	1.8333	0.009	0.004	1.9290	1.9167	1.9167	1.8333	1.9500	0.010	1.8119	0.0681
46	1.9167	1.6599	1.9583	1.951	1.8750	0.009	0.004	1.9707	1.9583	1.9583	1.8750	1.9917	0.010	1.8547	0.0681
47	1.9583	1.6960	2.0000	1.993	1.9167	0.009	0.004	2.0123	2.0000	2.0000	1.9167	2.0333	0.010	1.8952	0.0681
48	2.0000	1.7321	2.0417	2.035	1.9583	0.009	0.004	2.0540	2.0417	2.0417	1.9583	2.0750	0.010	1.9380	0.0681
49	2.0417	1.7681	2.0833	2.076	2.0000	0.009	0.004	2.0957	2.0833	2.0833	2.0000	2.1167	0.010	1.9788	0.0682
50	2.0833	1.8042	2.1250	2.118	2.0417	0.009	0.004	2.1373	2.1250	2.1250	2.0417	2.1583	0.010	2.0216	0.0682

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] $L = 0.0001 \times$ diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 16b—*24/48 Diametral Pitch, External*[a]

24/48 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0208 Dedendum (See Sec 6)	Circular Pitch, 0.1309 Meas-Pin Diam, 0.0800

EXTERNAL

	Major-diameter fit[b]								Fillet root[c]		Dimensions for all fits						
						Flat-root side fit									Tooth thickness		
N	Major diameter			Major-diam chamfer		Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.0649	0.0663	0.0684
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J[e])	+0.0000 −(0.0006 + J[e])	+0.0009 + J[e] −0.0000	App	Min	+0.0000 −0.0091	App	Max	+0.0000 −0.0030	+0.0000 −0.0091	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.2902	0.2916	0.2925	0.009	0.004	0.1960	0.007	0.007	0.2917	0.1667	—	0.2249	0.3655	0.3673	0.3701	0.0624	0.0638	0.0659
7	0.3318	0.3332	0.3341	0.010	0.004	0.2377	0.006	0.006	0.3333	0.2083	—	0.2624	0.3995	0.4013	0.4041	0.0624	0.0638	0.0659
8	0.3735	0.3749	0.3758	0.010	0.004	0.2793	0.006	0.006	0.3750	0.2500	—	0.2917	0.4498	0.4517	0.4546	0.0624	0.0638	0.0659
9	0.4152	0.4166	0.4175	0.010	0.004	0.3210	0.005	0.005	0.4167	0.2917	—	0.3333	0.4856	0.4875	0.4904	0.0624	0.0638	0.0659
10	0.4568	0.4582	0.4591	0.010	0.004	0.3627	0.005	0.005	0.4583	0.3333	—	0.3750	0.5337	0.5357	0.5387	0.0623	0.0627	0.0658
11	0.4985	0.4999	0.5009	0.010	0.004	0.4043	0.005	0.005	0.5000	0.3750	0.013	0.4167	0.5706	0.5726	0.5756	0.0623	0.0637	0.0658
12	0.5402	0.5416	0.5426	0.010	0.004	0.4460	0.005	0.004	0.5417	0.4167	0.013	0.4583	0.6176	0.6197	0.6227	0.0623	0.0637	0.0658
13	0.5818	0.5832	0.5842	0.010	0.004	0.4877	0.004	0.004	0.5833	0.4583	0.013	0.5000	0.6552	0.6572	0.6603	0.0623	0.0637	0.0658
14	0.6235	0.6249	0.6259	0.010	0.004	0.5293	0.004	0.004	0.6250	0.5000	0.012	0.5417	0.7014	0.7034	0.7065	0.0623	0.0637	0.0658
15	0.6652	0.6666	0.6676	0.010	0.004	0.5710	0.004	0.004	0.6667	0.5417	0.012	0.5833	0.7395	0.7416	0.7447	0.0623	0.0637	0.0658
16	0.7068	0.7082	0.7092	0.010	0.004	0.6127	0.004	0.004	0.7083	0.5833	0.012	0.6250	0.7850	0.7871	0.7902	0.0623	0.0637	0.0658
17	0.7485	0.7499	0.7509	0.010	0.004	0.6543	0.004	0.004	0.7500	0.6250	0.012	0.6667	0.8236	0.8257	0.8288	0.0623	0.0637	0.0658
18	0.7902	0.7916	0.7926	0.010	0.004	0.6960	0.004	0.004	0.7917	0.6667	0.011	0.7083	0.8686	0.8707	0.8739	0.0623	0.0637	0.0658
19	0.8318	0.8332	0.8342	0.010	0.004	0.7377	0.004	0.004	0.8333	0.7083	0.011	0.7500	0.9075	0.9096	0.9128	0.0623	0.0637	0.0658
20	0.8735	0.8749	0.8759	0.010	0.004	0.7793	0.004	0.004	0.8750	0.7500	0.011	0.7917	0.9522	0.9543	0.9575	0.0623	0.0637	0.0658
21	0.9152	0.9166	0.9176	0.010	0.004	0.8210	0.004	0.003	0.9167	0.7917	0.011	0.8333	0.9914	0.9935	0.9967	0.0623	0.0637	0.0658
22	0.9568	0.9582	0.9592	0.010	0.004	0.8627	0.004	0.003	0.9583	0.8333	0.011	0.8750	1.0356	1.0378	1.0410	0.0623	0.0637	0.0658
23	0.9985	0.9999	1.0009	0.010	0.004	0.9043	0.004	0.003	1.0000	0.8750	0.011	0.9167	1.0751	1.0773	1.0805	0.0623	0.0637	0.0658
24	1.0402	1.0416	1.0426	0.010	0.004	0.9460	0.004	0.003	1.0417	0.9167	0.011	0.9583	1.1192	1.1214	1.1246	0.0623	0.0637	0.0658
25	1.0818	1.0832	1.0842	0.010	0.004	0.9877	0.004	0.003	1.0833	0.9583	0.010	1.0000	1.1588	1.1610	1.1642	0.0623	0.0637	0.0658
26	1.1235	1.1249	1.1259	0.010	0.004	1.0293	0.004	0.003	1.1250	1.0000	0.010	1.0417	1.2027	1.2048	1.2081	0.0623	0.0637	0.0658
27	1.1652	1.1666	1.1676	0.010	0.004	1.0710	0.004	0.003	1.1667	1.0417	0.010	1.0833	1.2424	1.2445	1.2478	0.0623	0.0637	0.0658
28	1.2068	1.2082	1.2092	0.010	0.004	1.1127	0.004	0.003	1.2083	1.0833	0.010	1.1250	1.2860	1.2882	1.2915	0.0622	0.0636	0.0657
29	1.2485	1.2499	1.2509	0.010	0.004	1.1543	0.004	0.003	1.2500	1.1250	0.010	1.1667	1.3259	1.3281	1.3314	0.0622	0.0636	0.0657
30	1.2902	1.2916	1.2926	0.010	0.004	1.1960	0.004	0.003	1.2917	1.1667	0.010	1.2083	1.3694	1.3716	1.3749	0.0622	0.0636	0.0657
31	1.3318	1.3332	1.3342	0.010	0.004	1.2377	0.004	0.003	1.3333	1.2083	0.010	1.2500	1.4093	1.4116	1.4149	0.0622	0.0636	0.0657
32	1.3735	1.3749	1.3759	0.010	0.004	1.2793	0.004	0.003	1.3750	1.2500	0.010	1.2917	1.4528	1.4550	1.4584	0.0622	0.0636	0.0657
33	1.4152	1.4166	1.4176	0.010	0.004	1.3210	0.004	0.003	1.4167	1.2917	0.010	1.3333	1.4929	1.4951	1.4985	0.0622	0.0636	0.0657
34	1.4568	1.4582	1.4592	0.010	0.004	1.3627	0.004	0.003	1.4583	1.3333	0.010	1.3750	1.5362	1.5384	1.5418	0.0622	0.0636	0.0657
35	1.4985	1.4999	1.5010	0.010	0.004	1.4043	0.004	0.003	1.5000	1.3750	0.010	1.4167	1.5764	1.5786	1.5820	0.0622	0.0636	0.0657
36	1.5402	1.5416	1.5427	0.010	0.004	1.4460	0.004	0.003	1.5417	1.4167	0.010	1.4583	1.6196	1.6218	1.6252	0.0622	0.0636	0.0657
37	1.5818	1.5832	1.5843	0.010	0.004	1.4877	0.004	0.003	1.5833	1.4583	0.010	1.5000	1.6599	1.6621	1.6655	0.0622	0.0636	0.0657
38	1.6235	1.6249	1.6260	0.010	0.004	1.5293	0.004	0.003	1.6250	1.5000	0.010	1.5417	1.7031	1.7053	1.7087	0.0622	0.0636	0.0657
39	1.6652	1.6666	1.6677	0.010	0.004	1.5710	0.004	0.003	1.6667	1.5417	0.010	1.5833	1.7434	1.7456	1.7490	0.0622	0.0636	0.0657
40	1.7068	1.7082	1.7093	0.010	0.004	1.6127	0.004	0.003	1.7083	1.5833	0.009	1.6250	1.7864	1.7887	1.7921	0.0622	0.0636	0.0657
41	1.7485	1.7499	1.7510	0.010	0.004	1.6543	0.004	0.003	1.7500	1.6250	0.009	1.6667	1.8268	1.8291	1.8325	0.0622	0.0636	0.0657
42	1.7902	1.7916	1.7927	0.010	0.004	1.6960	0.004	0.003	1.7917	1.6667	0.009	1.7083	1.8698	1.8721	1.8755	0.0622	0.0636	0.0657
43	1.8318	1.8332	1.8343	0.010	0.004	1.7377	0.004	0.003	1.8333	1.7083	0.009	1.7500	1.9103	1.9126	1.9160	0.0622	0.0636	0.0657
44	1.8735	1.8749	1.8760	0.010	0.004	1.7793	0.004	0.003	1.8750	1.7500	0.009	1.7917	1.9532	1.9555	1.9589	0.0622	0.0636	0.0657
45	1.9152	1.9166	1.9177	0.010	0.004	1.8210	0.004	0.003	1.9167	1.7917	0.009	1.8333	1.9937	1.9960	1.9994	0.0622	0.0636	0.0657
46	1.9568	1.9582	1.9593	0.010	0.004	1.8627	0.004	0.003	1.9583	1.8333	0.009	1.8750	2.0366	2.0389	2.0423	0.0622	0.0636	0.0657
47	1.9985	1.9999	2.0010	0.010	0.004	1.9043	0.004	0.003	2.0000	1.8750	0.009	1.9167	2.0770	2.0793	2.0827	0.0621	0.0635	0.0656
48	2.0402	2.0416	2.0427	0.010	0.004	1.9460	0.004	0.003	2.0417	1.9167	0.009	1.9583	2.1198	2.1221	2.1255	0.0621	0.0635	0.0656
49	2.0818	2.0832	2.0843	0.010	0.004	1.9877	0.004	0.003	2.0833	1.9583	0.009	2.0000	2.1604	2.1627	2.1661	0.0621	0.0635	0.0656
50	2.1235	2.1249	2.1260	0.010	0.004	2.0293	0.004	0.003	2.1250	2.0000	0.009	2.0417	2.2032	2.2055	2.2089	0.0621	0.0635	0.0656

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 16a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 17a—*32/64 Diametral Pitch, Internal*[a]

32/64 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0156 Dedendum (See Sec 6)	Circular Pitch, 0.0982 Meas-Pin Diam, 0.0450

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits	
					Flat-Root Side Fit										
						Major diam fillet		Major diam						Space width	
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad	Measurement between pins	Min effective 0.0491
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance ⟶			+0.0007 + L[d] −0.0000	Min	+0.0015 −0.0000	App	Max	+0.0081 −0.0000	+0.0007 + L[d] −(0.0007 + L)	Min	+0.0015 −0.0000	+0.0081 −0.0000	Min[e]	Max	Dimensional Max[f]
6	0.1875	0.1624	0.2188	0.216	0.1687	0.005	0.002	0.2290	0.2188	0.2188	0.1687	0.2438	—	0.1419	0.0515
7	0.2188	0.1894	0.2500	0.247	0.1967	0.005	0.002	0.2603	0.2500	0.2500	0.1967	0.2750	—	0.1678	0.0516
8	0.2500	0.2165	0.2813	0.278	0.2188	0.005	0.002	0.2915	0.2813	0.2813	0.2188	0.3063	—	0.2045	0.0516
9	0.2813	0.2436	0.3125	0.309	0.2500	0.006	0.002	0.3228	0.3125	0.3125	0.2500	0.3375	0.003	0.2314	0.0516
10	0.3125	0.2706	0.3438	0.341	0.2813	0 006	0.002	0.3540	0.3438	0.3438	0.2813	0.3688	0.004	0.2670	0.0516
11	0.3438	0.2977	0.3750	0.372	0.3125	0.006	0.002	0.3853	0.3750	0.3750	0.3125	0.4000	0.004	0.2947	0.0516
12	0.3750	0.3248	0.4063	0.401	0.3438	0.006	0.003	0.4165	0.4063	0.4063	0.3438	0.4313	0.004	0.3294	0.0516
13	0.4063	0.3518	0.4375	0.432	0.3750	0.006	0.003	0.4478	0.4375	0.4375	0.3750	0.4625	0.005	0.3578	0.0516
14	0.4375	0.3789	0.4688	0.464	0.4063	0.006	0.003	0.4790	0.4688	0.4688	0.4063	0.4938	0.005	0.3919	0.0516
15	0.4688	0.4059	0.5000	0.495	0 4375	0.006	0 003	0.5103	0.5000	0.5000	0.4375	0.5250	0.005	0.4206	0.0516
16	0.5000	0.4330	0.5313	0.526	0.4688	0.006	0.003	0.5415	0.5313	0.5313	0.4688	0.5563	0.005	0.4544	0.0516
17	0.5313	0.4601	0.5625	0.557	0.5000	0.006	0.003	0.5728	0.5625	0.5625	0.5000	0.5875	0.005	0.4834	0.0516
18	0.5625	0.4871	0.5938	0.589	0.5313	0.006	0.003	0.6040	0.5938	0.5938	0.5313	0.6188	0.006	0.5170	0.0516
19	0.5938	0.5142	0.6250	0.620	0.5625	0.007	0.003	0.6353	0.6250	0.6250	0.5625	0.6500	0.006	0.5461	0.0516
20	0.6250	0.5413	0.6563	0.651	0.5938	0.007	0.003	0.6665	0.6563	0.6563	0.5938	0.6813	0.006	0.5794	0.0516
21	0.6563	0.5683	0.6875	0.682	0.6250	0.007	0.003	0.6978	0.6875	0.6875	0.6250	0.7125	0.006	0.6090	0.0517
22	0.6875	0.5954	0.7188	0.714	0.6563	0.007	0.003	0.7290	0.7188	0.7188	0.6563	0.7438	0.006	0.6421	0.0517
23	0.7188	0.6225	0.7500	0.745	0.6875	0.007	0.003	0.7603	0.7500	0.7500	0.6875	0.7750	0.006	0.6717	0.0517
24	0.7500	0.6495	0.7813	0.776	0.7188	0.007	0.003	0.7915	0.7813	0.7813	0.7188	0.8063	0.006	0.7046	0.0517
25	0.7813	0.6766	0.8125	0.807	0.7500	0.007	0.003	0.8228	0.8125	0.8125	0.7500	0.8375	0.006	0.7343	0.0517
26	0.8125	0.7036	0.8438	0.839	0.7813	0.007	0.003	0.8540	0.8438	0.8438	0.7813	0.8688	0.006	0.7671	0.0517
27	0.8438	0.7307	0.8750	0.870	0.8125	0.007	0.003	0.8853	0.8750	0.8750	0.8125	0.9000	0.006	0.7969	0.0517
28	0.8750	0.7578	0.9063	0.901	0.8438	0.007	0.003	0.9165	0.9063	0.9063	0.8438	0.9313	0.006	0.8296	0.0517
29	0.9063	0.7848	0.9375	0.932	0.8750	0.007	0.003	0.9478	0.9375	0.9375	0.8750	0.9625	0.006	0.8595	0.0517
30	0.9375	0.8119	0.9688	0.964	0.9063	0.007	0.003	0.9790	0.9688	0.9688	0.9063	0.9938	0.007	0.8921	0.0517
31	0.9688	0.8390	1.0000	0.995	0.9375	0.007	0.003	1.0103	1.0000	1.0000	0.9375	1.0250	0.007	0.9221	0.0517
32	1.0000	0.8660	1.0313	1.026	0.9688	0.007	0.003	1.0415	1.0313	1.0313	0.9688	1.0563	0.007	0.9546	0.0517
33	1.0313	0.8931	1.0625	1.057	1.0000	0.007	0.003	1.0728	1.0625	1.0625	1.0000	1.0875	0.007	0.9847	0.0517
34	1.0625	0.9202	1.0938	1.089	1.0313	0.007	0.003	1.1040	1.0938	1.0938	1.0313	1.1188	0.007	1.0171	0.0517
35	1.0938	0.9472	1.1250	1.120	1.0625	0.007	0.003	1.1353	1.1250	1.1250	1.0625	1.1500	0.007	1.0473	0.0518
36	1.1250	0.9743	1.1563	1.151	1.0938	0.007	0.003	1.1665	1.1563	1.1563	1.0938	1.1813	0.007	1.0797	0.0518
37	1.1563	1.0013	1.1875	1.182	1.1250	0.007	0.003	1.1978	1.1875	1.1875	1.1250	1.2125	0.007	1.1097	0.0518
38	1.1875	1.0284	1.2188	1.214	1.1563	0.007	0.003	1.2290	1.2188	1.2188	1.1563	1.2438	0.007	1.1422	0.0518
39	1.2188	1.0555	1.2500	1.245	1.1875	0.007	0.003	1.2603	1.2500	1.2500	1.1875	1.2750	0.007	1.1724	0.0518
40	1.2500	1.0825	1.2813	1.276	1.2188	0.007	0.003	1.2915	1.2813	1.2813	1.2188	1.3063	0.007	1.2047	0.0518
41	1.2813	1.1096	1.3125	1.307	1.2500	0.007	0.003	1.3228	1.3125	1.3125	1.2500	1.3375	0.007	1.2350	0.0518
42	1.3125	1.1367	1.3438	1.339	1.2813	0.007	0.003	1.3540	1.3438	1.3438	1.2813	1.3688	0.007	1.2672	0.0518
43	1.3438	1.1637	1.3750	1.370	1.3125	0.007	0.003	1.3853	1.3750	1.3750	1.3125	1.4000	0.007	1.2975	0.0518
44	1.3750	1.1908	1.4063	1.401	1.3438	0.007	0.003	1.4165	1.4063	1.4063	1.3438	1.4313	0.007	1.3297	0.0518
45	1.4063	1.2178	1.4375	1.432	1.3750	0.007	0.003	1.4478	1.4375	1.4375	1.3750	1.4625	0.007	1.3601	0.0518
46	1.4375	1.2449	1.4688	1.464	1.4063	0.007	0.003	1.4790	1.4688	1.4688	1.4063	1.4938	0.007	1.3922	0.0518
47	1.4688	1.2720	1.5000	1.495	1.4375	0.007	0.003	1.5103	1.5000	1.5000	1.4375	1.5250	0.007	1.4226	0.0518
48	1.5000	1.2990	1.5313	1.526	1.4688	0.007	0.003	1.5415	1.5313	1.5313	1.4688	1.5563	0.007	1.4547	0.0518
49	1.5313	1.3261	1.5625	1.557	1.5000	0.007	0.003	1.5728	1.5625	1.5625	1.5000	1.5875	0.007	1.4854	0.0519
50	1.5625	1.3532	1.5938	1.589	1.5313	0.007	0.003	1.6040	1.5938	1.5938	1.5313	1.6188	0.007	1.5174	0.0519

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 17b—*32/64 Diametral Pitch, External*[a]

32/64 Diametral Pitch
Pressure Angle, 30°

Addendum (Basic), 0.0156
Dedendum (See Sec 6)

Circular Pitch, 0.0982
Meas-Pin Diam, 0.0600

EXTERNAL

N	Major-diameter fit[b]								Fillet root[c]			Dimensions for all fits						
	Major diameter			Major-diam chamfer		Flat-root side fit									Tooth thickness			
						Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.0486	0.0500	0.0521
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J^e)	+0.0000 −(0.0006 + J^e)	+0.0009 + J^e −0.0000	App	Min	+0.0000 −0.0081	App	Max	+0.0000 −0.0030	+0.0000 −0.0081	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.2173	0.2187	0.2196	0.007	0.003	0.1460	0.005	0.005	0.2188	0.1250	—	0.1687	0.2732	0.2750	0.2778	0.0461	0.0475	0.0496
7	0.2485	0.2499	0.2508	0.007	0.003	0.1773	0.005	0.005	0.2500	0.1563	—	0.1967	0.2987	0.3005	0.3033	0.0461	0.0475	0.0496
8	0.2798	0.2812	0.2821	0.007	0.003	0.2085	0.004	0.004	0.2813	0.1875	—	0.2188	0.3364	0.3383	0.3412	0.0461	0.0475	0.0496
9	0.3110	0.3124	0.3133	0.007	0.003	0.2398	0.004	0.004	0.3125	0.2188	—	0.2500	0.3632	0.3651	0.3680	0.0461	0.0475	0.0496
10	0.3423	0.3437	0.3446	0.007	0.003	0.2710	0.004	0.004	0.3438	0.2500	—	0.2813	0.3992	0.4012	0.4042	0.0460	0.0474	0.0495
11	0.3735	0.3749	0.3758	0.007	0.003	0.3023	0.004	0.004	0.3750	0.2813	0.010	0.3125	0.4269	0.4289	0.4319	0.0460	0.0474	0.0495
12	0.4048	0.4062	0.4071	0.007	0.003	0.3335	0.003	0.003	0.4063	0.3125	0.010	0.3438	0.4620	0.4641	0.4671	0.0460	0.0474	0.0495
13	0.4360	0.4374	0.4383	0.007	0.003	0.3648	0.003	0.003	0.4375	0.3438	0.009	0.3750	0.4903	0.4923	0.4954	0.0460	0.0474	0.0495
14	0.4673	0.4687	0.4696	0.007	0.003	0.3960	0.003	0.003	0.4688	0.3750	0.009	0.4063	0.5249	0.5269	0.5300	0.0460	0.0474	0.0495
15	0.4985	0.4999	0.5009	0.007	0.003	0.4273	0.003	0.003	0.5000	0.4063	0.009	0.4375	0.5535	0.5556	0.5587	0.0460	0.0474	0.0495
16	0.5298	0.5312	0.5322	0.007	0.003	0.4585	0.003	0.003	0.5313	0.4375	0.009	0.4688	0.5876	0.5897	0.5928	0.0460	0.0474	0.0495
17	0.5610	0.5624	0.5634	0.007	0.003	0.4898	0.003	0.003	0.5625	0.4688	0.008	0.5000	0.6166	0.6187	0.6218	0.0460	0.0474	0.0495
18	0.5923	0.5937	0.5947	0.007	0.003	0.5210	0.003	0.003	0.5938	0.5000	0.008	0.5313	0.6503	0.6524	0.6556	0.0460	0.0474	0.0495
19	0.6235	0.6249	0.6259	0.007	0.003	0.5523	0.003	0.003	0.6250	0.5313	0.008	0.5625	0.6795	0.6816	0.6848	0.0460	0.0474	0.0495
20	0.6548	0.6562	0.6572	0.007	0.003	0.5835	0.003	0.003	0.6563	0.5625	0.008	0.5938	0.7130	0.7151	0.7183	0.0460	0.0474	0.0495
21	0.6860	0.6874	0.6884	0.007	0.003	0.6148	0.003	0.003	0.6875	0.5938	0.008	0.6250	0.7424	0.7445	0.7477	0.0460	0.0474	0.0495
22	0.7173	0.7187	0.7197	0.007	0.003	0.6460	0.003	0.003	0.7188	0.6250	0.008	0.6563	0.7755	0.7777	0.7809	0.0460	0.0474	0.0495
23	0.7485	0.7499	0.7509	0.007	0.003	0.6773	0.003	0.003	0.7500	0.6563	0.008	0.6875	0.8051	0.8073	0.8105	0.0460	0.0474	0.0495
24	0.7798	0.7812	0.7822	0.007	0.003	0.7085	0.003	0.003	0.7813	0.6875	0.008	0.7188	0.8382	0.8404	0.8436	0.0460	0.0474	0.0495
25	0.8110	0.8124	0.8134	0.007	0.003	0.7398	0.003	0.002	0.8125	0.7188	0.008	0.7500	0.8679	0.8701	0.8733	0.0460	0.0474	0.0495
26	0.8423	0.8437	0.8447	0.007	0.003	0.7710	0.003	0.002	0.8438	0.7500	0.007	0.7813	0.9008	0.9029	0.9062	0.0460	0.0474	0.0495
27	0.8735	0.8749	0.8759	0.007	0.003	0.8023	0.003	0.002	0.8750	0.7813	0.007	0.8125	0.9306	0.9327	0.9360	0.0460	0.0474	0.0495
28	0.9048	0.9062	0.9072	0.007	0.003	0.8335	0.003	0.002	0.9063	0.8125	0.007	0.8438	0.9632	0.9654	0.9687	0.0459	0.0473	0.0494
29	0.9360	0.9374	0.9384	0.007	0.003	0.8648	0.003	0.002	0.9375	0.8438	0.007	0.8750	0.9931	0.9953	0.9986	0.0459	0.0473	0.0494
30	0.9673	0.9687	0.9697	0.007	0.003	0.8960	0.003	0.002	0.9688	0.8750	0.007	0.9063	1.0258	1.0280	1.0313	0.0459	0.0473	0.0494
31	0.9985	0.9999	1.0009	0.007	0.003	0.9273	0.003	0.002	1.0000	0.9063	0.007	0.9375	1.0557	1.0580	1.0613	0.0459	0.0473	0.0494
32	1.0298	1.0312	1.0322	0.007	0.003	0.9585	0.003	0.002	1.0313	0.9375	0.007	0.9688	1.0883	1.0905	1.0939	0.0459	0.0473	0.0494
33	1.0610	1.0624	1.0634	0.007	0.003	0.9898	0.003	0.002	1.0625	0.9688	0.007	1.0000	1.1184	1.1206	1.1240	0.0459	0.0473	0.0494
34	1.0923	1.0937	1.0947	0.007	0.003	1.0210	0.003	0.002	1.0938	1.0000	0.007	1.0313	1.1509	1.1531	1.1565	0.0459	0.0473	0.0494
35	1.1235	1.1249	1.1259	0.007	0.003	1.0523	0.003	0.002	1.1250	1.0313	0.007	1.0625	1.1810	1.1832	1.1866	0.0459	0.0473	0.0494
36	1.1548	1.1562	1.1572	0.008	0.003	1.0835	0.003	0.002	1.1563	1.0625	0.007	1.0938	1.2135	1.2157	1.2191	0.0459	0.0473	0.0494
37	1.1860	1.1874	1.1884	0.008	0.003	1.1148	0.003	0.002	1.1875	1.0938	0.007	1.1250	1.2437	1.2459	1.2493	0.0459	0.0473	0.0494
38	1.2173	1.2187	1.2197	0.008	0.003	1.1460	0.003	0.002	1.2188	1.1250	0.007	1.1563	1.2760	1.2782	1.2816	0.0459	0.0473	0.0494
39	1.2485	1.2499	1.2509	0.008	0.003	1.1773	0.003	0.002	1.2500	1.1563	0.007	1.1875	1.3063	1.3085	1.3119	0.0459	0.0473	0.0494
40	1.2798	1.2812	1.2822	0.088	0.003	1.2085	0.003	0.002	1.2813	1.1875	0.007	1.2188	1.3385	1.3408	1.3442	0.0459	0.0473	0.0494
41	1.3110	1.3124	1.3134	0.008	0.003	1.2398	0.003	0.002	1.3125	1.2188	0.007	1.2500	1.3688	1.3711	1.3744	0.0459	0.0473	0.0494
42	1.3423	1.3437	1.3447	0.008	0.003	1.2710	0.003	0.002	1.3438	1.2500	0.007	1.2813	1.4010	1.4033	1.4067	0.0459	0.0473	0.0494
43	1.3735	1.3749	1.3759	0.008	0.003	1.3023	0.003	0.002	1.3750	1.2813	0.007	1.3125	1.4314	1.4337	1.4371	0.0459	0.0473	0.0494
44	1.4048	1.4062	1.4072	0.008	0.003	1.3335	0.003	0.002	1.4063	1.3125	0.007	1.3438	1.4636	1.4659	1.4693	0.0459	0.0473	0.0494
45	1.4360	1.4374	1.4384	0.008	0.003	1.3648	0.003	0.002	1.4375	1.3438	0.007	1.3750	1.4940	1.4963	1.4997	0.0459	0.0473	0.0494
46	1.4673	1.4687	1.4697	0.008	0.003	1.3960	0.003	0.002	1.4688	1.3750	0.007	1.4063	1.5261	1.5284	1.5318	0.0459	0.0473	0.0494
47	1.4985	1.4999	1.5010	0.008	0.003	1.4273	0.003	0.002	1.5000	1.4063	0.007	1.4375	1.5564	1.5587	1.5621	0.0458	0.0472	0.0493
48	1.5298	1.5312	1.5323	0.008	0.003	1.4585	0.003	0.002	1.5313	1.4375	0.006	1.4688	1.5885	1.5908	1.5942	0.0458	0.0472	0.0493
49	1.5610	1.5624	1.5635	0.008	0.003	1.4898	0.003	0.002	1.5625	1.4688	0.006	1.5000	1.6191	1.6214	1.6248	0.0458	0.0472	0.0493
50	1.5923	1.5937	1.5948	0.008	0.003	1.5210	0.003	0.002	1.5938	1.5000	0.006	1.5313	1.6510	1.6533	1.6567	0.0458	0.0472	0.0493

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 17a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 18a—*40/80 Diametral Pitch, Internal*[a]

40/80 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0125 Dedendum (See Sec 6)	Circular Pitch, 0.0785 Meas-Pin Diam, 0.0360

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits	
					Flat-Root Side Fit									Space width	
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Major-diam fillet		Major diam		*TIF* diam	Minor diam	Major diam	Fillet rad	Measurement between pins	Min effective 0.0393
						Rad	Ht	Full deden[b]	Short deden[c]						
1	2	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance ⟶			$+0.0007 + L^d - 0.0000$	Min	$+0.0015 - 0.0000$	App	Max	$+0.0075 - 0.0000$	$+0.0007 + L^d - (0.0007 + L)$	Min	$+0.0015 - 0.0000$	$+0.0075 - 0.0000$	Min[e]	Max	Dimensional Max[f]
6	0.1500	0.1299	0.1750	0.174	0.1349	0.004	0.001	0.1840	0.1750	0.1750	0.1349	0.1950	—	0.1144	0.0417
7	0.1750	0.1516	0.2000	0.197	0.1575	0.004	0.002	0.2090	0.2000	0.2000	0.1575	0.2200	—	0.1352	0.0418
8	0.2000	0.1732	0.2250	0.222	0.1750	0.004	0.002	0.2340	0.2250	0.2250	0.1750	0.2450	—	0.1645	0.0418
9	0.2250	0.1949	0.2500	0.247	0.2000	0.004	0.002	0.2590	0.2500	0.2500	0.2000	0.2700	0.002	0.1860	0.0418
10	0.2500	0.2165	0.2750	0.272	0.2250	0.005	0.002	0.2840	0.2750	0.2750	0.2250	0.2950	0.002	0.2145	0.0418
11	0.2750	0.2382	0.3000	0.297	0.2500	0.005	0.002	0.3090	0.3000	0.3000	0.2500	0.3200	0.003	0.2367	0.0418
12	0.3000	0.2598	0.3250	0.322	0.2750	0.005	0.002	0.3340	0.3250	0.3250	0.2750	0.3450	0.003	0.2644	0.0418
13	0.3250	0.2815	0.3500	0.347	0.3000	0.005	0.002	0.3590	0.3500	0.3500	0.3000	0.3700	0.003	0.2871	0.0418
14	0.3500	0.3031	0.3750	0.372	0.3250	0.005	0.002	0.3840	0.3750	0.3750	0.3250	0.3950	0.003	0.3144	0.0418
15	0.3750	0.3248	0.4000	0.397	0.3500	0.005	0.002	0.4090	0.4000	0.4000	0.3500	0.4200	0.003	0.3374	0.0418
16	0.4000	0.3464	0.4250	0.422	0.3750	0.005	0.002	0.4340	0.4250	0.4250	0.3750	0.4450	0.004	0.3645	0.0418
17	0.4250	0.3681	0.4500	0.447	0.4000	0.005	0.002	0.4590	0.4500	0.4500	0.4000	0.4700	0.004	0.3876	0.0418
18	0.4500	0.3897	0.4750	0.472	0.4250	0.005	0.002	0.4840	0.4750	0.4750	0.4250	0.4950	0.004	0.4145	0.0418
19	0.4750	0.4114	0.5000	0.497	0.4500	0.005	0.002	0.5090	0.5000	0.5000	0.4500	0.5200	0.004	0.4378	0.0418
20	0.5000	0.4330	0.5250	0.522	0.4750	0.005	0.002	0.5340	0.5250	0.5250	0.4750	0.5450	0.004	0.4644	0.0418
21	0.5250	0.4547	0.5500	0.547	0.5000	0.005	0.002	0.5590	0.5500	0.5500	0.5000	0.5700	0.004	0.4881	0.0419
22	0.5500	0.4763	0.5750	0.572	0.5250	0.005	0.002	0.5840	0.5750	0.5750	0.5250	0.5950	0.004	0.5146	0.0419
23	0.5750	0.4980	0.6000	0.597	0.5500	0.005	0.002	0.6090	0.6000	0.6000	0.5500	0.6200	0.004	0.5383	0.0419
24	0.6000	0.5196	0.6250	0.622	0.5750	0.005	0.002	0.6340	0.6250	0.6250	0.5750	0.6450	0.004	0.5646	0.0419
25	0.6250	0.5413	0.6500	0.647	0.6000	0.005	0.002	0.6590	0.6500	0.6500	0.6000	0.6700	0.004	0.5884	0.0419
26	0.6500	0.5629	0.6750	0.670	0.6250	0.005	0.003	0.6840	0.6750	0.6750	0.6250	0.6950	0.005	0.6146	0.0419
27	0.6750	0.5846	0.7000	0.695	0.6500	0.005	0.003	0.7090	0.7000	0.7000	0.6500	0.7200	0.005	0.6385	0.0419
28	0.7000	0.6062	0.7250	0.720	0.6750	0.005	0.003	0.7340	0.7250	0.7250	0.6750	0.7450	0.005	0.6646	0.0419
29	0.7250	0.6279	0.7500	0.745	0.7000	0.005	0.003	0.7590	0.7500	0.7500	0.7000	0.7700	0.005	0.6886	0.0419
30	0.7500	0.6495	0.7750	0.770	0.7250	0.005	0.003	0.7840	0.7750	0.7750	0.7250	0.7950	0.005	0.7146	0.0419
31	0.7750	0.6712	0.8000	0.795	0.7500	0.005	0.003	0.8090	0.8000	0.8000	0.7500	0.8200	0.005	0.7386	0.0419
32	0.8000	0.6928	0.8250	0.820	0.7750	0.005	0.003	0.8340	0.8250	0.8250	0.7750	0.8450	0.005	0.7646	0.0419
33	0.8250	0.7145	0.8500	0.845	0.8000	0.005	0.003	0.8590	0.8500	0.8500	0.8000	0.8700	0.005	0.7887	0.0419
34	0.8500	0.7361	0.8750	0.870	0.8250	0.005	0.003	0.8840	0.8750	0.8750	0.8250	0.8950	0.005	0.8146	0.0419
35	0.8750	0.7578	0.9000	0.895	0.8500	0.005	0.003	0.9090	0.9000	0.9000	0.8500	0.9200	0.005	0.8388	0.0420
36	0.9000	0.7794	0.9250	0.920	0.8750	0.006	0.003	0.9340	0.9250	0.9250	0.8750	0.9450	0.005	0.8647	0.0420
37	0.9250	0.8011	0.9500	0.945	0.9000	0.006	0.003	0.9590	0.9500	0.9500	0.9000	0.9700	0.005	0.8889	0.0420
38	0.9500	0.8227	0.9750	0.970	0.9250	0.006	0.003	0.9840	0.9750	0.9750	0.9250	0.9950	0.005	0.9147	0.0420
39	0.9750	0.8444	1.0000	0.995	0.9500	0.006	0.003	1.0090	1.0000	1.0000	0.9500	1.0200	0.005	0.9389	0.0420
40	1.0000	0.8660	1.0250	1.020	0.9750	0.006	0.003	1.0340	1.0250	1.0250	0.9750	1.0450	0.005	0.9647	0.0420
41	1.0250	0.8877	1.0500	1.045	1.0000	0.006	0.003	1.0590	1.0500	1.0500	1.0000	1.0700	0.005	0.9889	0.0420
42	1.0500	0.9093	1.0750	1.070	1.0250	0.006	0.003	1.0840	1.0750	1.0750	1.0250	1.095	0.005	1.0147	0.0420
43	1.0750	0.9310	1.1000	1.095	1.0500	0.006	0.003	1.1090	1.1000	1.1000	1.0500	1.120	0.005	1.0390	0.0420
44	1.1000	0.9526	1.1250	1.120	1.0750	0.006	0.003	1.1340	1.1250	1.1250	1.0750	1.1450	0.005	1.0647	0.0420
45	1.1250	0.9743	1.1500	1.145	1.1000	0.006	0.003	1.1590	1.1500	1.1500	1.1000	1.1700	0.005	1.0890	0.0420
46	1.1500	0.9959	1.1750	1.170	1.1250	0.006	0.003	1.1840	1.1750	1.1750	1.1250	1.1950	0.005	1.1147	0.0420
47	1.1750	1.0176	1.2000	1.195	1.1500	0.006	0.003	1.2090	1.2000	1.2000	1.1500	1.2200	0.005	1.1390	0.0420
48	1.2000	1.0392	1.2250	1.220	1.1750	0.006	0.003	1.2340	1.2250	1.2250	1.1750	1.2450	0.005	1.1647	0.0420
49	1.2250	1.0609	1.2500	1.245	1.2000	0.006	0.003	1.2590	1.2500	1.2500	1.2000	1.2700	0.005	1.1893	0.0421
50	1.2500	1.0825	1.2750	1.270	1.2250	0.006	0.003	1.2840	1.2750	1.2750	1.2250	1.2950	0.005	1.2149	0.0421

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 18b—*40/80 Diametral Pitch, External*[a]

40/80 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0125 Dedendum (See Sec 6)	Circular Pitch, 0.0785 Meas-Pin Diam, 0.0480

EXTERNAL

N	Major-diameter fit[b]								Fillet root[c]			Dimensions for all fits					
	Major diameter			Major-diam chamfer		Flat-root side fit									Tooth thickness		
						Minor diam	Minor-diam fillet		Major diam[d]	Minor diam	Fil rad	*TIF* diam	Measurement over pins			Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.0388	0.0402	0.0423
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J[e])	+0.0000 −(0.0006 + J[e])	+0.0009 + J[e] −0.0000	App	Min	+0.0000 −0.0075	App	Max	+0.0000 −0.0030	+0.0000 −0.0075	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.1735	0.1749	0.1758	0.006	0.002	0.1160	0.004	0.004	0.1750	0.1000	—	0.1349	0.2178	0.2196	0.2224	0.0363	0.0377	0.0398
7	0.1985	0.1999	0.2008	0.006	0.002	0.1410	0.004	0.004	0.2000	0.1250	—	0.1575	0.2382	0.2400	0.2428	0.0363	0.0377	0.0398
8	0.2235	0.2249	0.2258	0.006	0.002	0.1660	0.004	0.003	0.2250	0.1500	—	0.1750	0.2683	0.2702	0.2731	0.0363	0.0377	0.0398
9	0.2485	0.2499	0.2508	0.006	0.002	0.1910	0.003	0.003	0.2500	0.1750	—	0.2000	0.2897	0.2916	0.2945	0.0363	0.0377	0.0398
10	0.2735	0.2749	0.2758	0.006	0.002	0.2160	0.003	0.003	0.2750	0.2000	—	0.2250	0.3185	0.3205	0.3235	0.0362	0.0376	0.0397
11	0.2985	0.2999	0.3008	0.006	0.002	0.2410	0.003	0.003	0.3000	0.2250	0.008	0.2500	0.3406	0.3426	0.3456	0.0362	0.0376	0.0397
12	0.3235	0.3249	0.3258	0.006	0.003	0.2660	0.003	0.003	0.3250	0.2500	0.008	0.2750	0.3687	0.3708	0.3738	0.0362	0.0376	0.0397
13	0.3485	0.3499	0.3508	0.006	0.003	0.2910	0.003	0.003	0.3500	0.2750	0.007	0.3000	0.3913	0.3933	0.3964	0.0362	0.0376	0.0397
14	0.3735	0.3749	0.3758	0.006	0.003	0.3160	0.003	0.002	0.3750	0.3000	0.007	0.3250	0.4190	0.4210	0.4241	0.0362	0.0376	0.0397
15	0.3985	0.3999	0.4008	0.006	0.003	0.3410	0.003	0.002	0.4000	0.3250	0.007	0.3500	0.4419	0.4440	0.4471	0.0362	0.0376	0.0397
16	0.4235	0.4249	0.4258	0.006	0.003	0.3660	0.003	0.002	0.4250	0.3500	0.007	0.3750	0.4692	0.4713	0.4744	0.0362	0.0376	0.0387
17	0.4485	0.4499	0.4508	0.006	0.003	0.3910	0.003	0.002	0.4500	0.3750	0.007	0.4000	0.4924	0.4945	0.4976	0.0362	0.0376	0.0397
18	0.4735	0.4749	0.4758	0.006	0.003	0.4160	0.003	0.002	0.4750	0.4000	0.006	0.4250	0.5193	0.5214	0.5246	0.0362	0.0376	0.0397
19	0.4985	0.4999	0.5009	0.006	0.003	0.4410	0.003	0.002	0.5000	0.4250	0.006	0.4500	0.5426	0.5447	0.5479	0.0362	0.0376	0.0397
20	0.5235	0.5249	0.5259	0.006	0.003	0.4660	0.003	0.002	0.5250	0.4500	0.006	0.4750	0.5694	0.5715	0.5747	0.0362	0.0376	0.0397
21	0.5485	0.5499	0.5509	0.006	0.003	0.4910	0.003	0.002	0.5500	0.4750	0.006	0.5000	0.5930	0.5951	0.5983	0.0362	0.0376	0.0397
22	0.5735	0.5749	0.5759	0.006	0.003	0.5160	0.003	0.002	0.5750	0.5000	0.006	0.5250	0.6195	0.6217	0.6249	0.0362	0.0376	0.0397
23	0.5985	0.5999	0.6009	0.006	0.003	0.5410	0.003	0.002	0.6000	0.5250	0.006	0.5500	0.6431	0.6453	0.6485	0.0362	0.0376	0.0397
24	0.6235	0.6249	0.6259	0.006	0.003	0.5660	0.003	0.002	0.6250	0.5500	0.006	0.5750	0.6696	0.6718	0.6750	0.0362	0.0376	0.0397
25	0.6485	0.6499	0.6509	0.006	0.003	0.5910	0.003	0.002	0.6500	0.5750	0.006	0.6000	0.6934	0.6956	0.6988	0.0362	0.0376	0.0397
26	0.6735	0.6749	0.6759	0.006	0.003	0.6160	0.003	0.002	0.6750	0.6000	0.006	0.6250	0.7197	0.7218	0.7251	0.0362	0.0376	0.0397
27	0.6985	0.6999	0.7009	0.006	0.003	0.6410	0.003	0.002	0.7000	0.6250	0.006	0.6500	0.7435	0.7456	0.7489	0.0362	0.0376	0.0397
28	0.7235	0.7249	0.7259	0.006	0.003	0.6660	0.003	0.002	0.7250	0.6500	0.006	0.6750	0.7696	0.7718	0.7751	0.0361	0.0375	0.0396
29	0.7485	0.7499	0.7509	0.006	0.003	0.6910	0.003	0.002	0.7500	0.6750	0.006	0.7000	0.7935	0.7957	0.7990	0.0361	0.0375	0.0396
30	0.7735	0.7749	0.7759	0.006	0.003	0.7160	0.003	0.002	0.7750	0.7000	0.006	0.7250	0.8197	0.8219	0.8252	0.0361	0.0375	0.0396
31	0.7985	0.7999	0.8009	0.006	0.003	0.7410	0.003	0.002	0.8000	0.7250	0.005	0.7500	0.8436	0.8459	0.8492	0.0361	0.0375	0.0396
32	0.8235	0.8249	0.8259	0.006	0.003	0.7660	0.003	0.002	0.8250	0.7500	0.005	0.7750	0.8696	0.8718	0.8752	0.0361	0.0375	0.0396
33	0.8485	0.8499	0.8509	0.006	0.003	0.7910	0.003	0.002	0.8500	0.7750	0.005	0.8000	0.8937	0.8959	0.8993	0.0361	0.0375	0.0396
34	0.8735	0.8749	0.8759	0.006	0.003	0.8160	0.003	0.002	0.8750	0.8000	0.005	0.8250	0.9197	0.9219	0.9253	0.0361	0.0375	0.0396
35	0.8985	0.8999	0.9009	0.006	0.003	0.8410	0.003	0.002	0.9000	0.8250	0.005	0.8500	0.9438	0.9460	0.9494	0.0361	0.0375	0.0396
36	0.9235	0.9249	0.9259	0.006	0.003	0.8660	0.003	0.002	0.9250	0.8500	0.005	0.8750	0.9698	0.9720	0.9754	0.0361	0.0375	0.0396
37	0.9485	0.9499	0.9509	0.006	0.003	0.8910	0.003	0.002	0.9500	0.8750	0.005	0.9000	0.9939	0.9961	0.9995	0.0361	0.0375	0.0396
38	0.9735	0.9749	0.9759	0.006	0.003	0.9160	0.003	0.002	0.9750	0.9000	0.005	0.9250	1.0198	1.0220	1.0254	0.0361	0.0375	0.0396
39	0.9985	0.9999	1.0009	0.006	0.003	0.9410	0.003	0.002	1.0000	0.9250	0.005	0.9500	1.0440	1.0462	1.0496	0.0361	0.0375	0.0396
40	1.0235	1.0249	1.0259	0.006	0.003	0.9660	0.003	0.002	1.0250	0.9500	0.005	0.9750	1.0698	1.0721	1.0755	0.0361	0.0375	0.0396
41	1.0485	1.0499	1.0509	0.006	0.003	0.9910	0.003	0.002	1.0500	0.9750	0.005	1.0000	1.0940	1.0963	1.0997	0.0361	0.0375	0.0396
42	1.0735	1.0749	1.0759	0.006	0.003	1.0160	0.003	0.002	1.0750	1.0000	0.005	1.0250	1.1198	1.1221	1.1255	0.0361	0.0375	0.0396
43	1.0985	1.0999	1.1009	0.006	0.003	1.0410	0.003	0.002	1.1000	1.0250	0.005	1.0500	1.1441	1.1464	1.1498	0.0361	0.0375	0.0396
44	1.1235	1.1249	1.1259	0.006	0.003	1.0660	0.003	0.002	1.1250	1.0500	0.005	1.0750	1.1698	1.1721	1.1755	0.0361	0.0375	0.0396
45	1.1485	1.1499	1.1509	0.006	0.003	1.0910	0.003	0.002	1.1500	1.0750	0.005	1.1000	1.1942	1.1965	1.1999	0.0361	0.0375	0.0396
46	1.1735	1.1749	1.1759	0.006	0.003	1.1160	0.003	0.002	1.1750	1.1000	0.005	1.1250	1.2199	1.2222	1.2256	0.0361	0.0375	0.0396
47	1.1985	1.1999	1.2009	0.006	0.003	1.1410	0.003	0.002	1.2000	1.1250	0.005	1.1500	1.2440	1.2463	1.2497	0.0360	0.0374	0.0395
48	1.2235	1.2249	1.2259	0.006	0.003	1.1660	0.003	0.002	1.2250	1.1500	0.005	1.1750	1.2697	1.2720	1.2754	0.0360	0.0374	0.0395
49	1.2485	1.2499	1.2509	0.006	0.003	1.1910	0.003	0.002	1.2500	1.1750	0.005	1.2000	1.2941	1.2964	1.2998	0.0360	0.0374	0.0395
50	1.2735	1.2749	1.2759	0.006	0.003	1.2160	0.003	0.002	1.2750	1.2000	0.005	1.2250	1.3197	1.3220	1.3254	0.0360	0.0374	0.0395

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 18a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 19a—*48/96 Diametral Pitch, Internal*[a]

48/96 Diametral Pitch
Pressure Angle, 30°

Addendum (Basic), 0.0104
Dedendum (See Sec 6)

Circular Pitch, 0.0654
Meas-Pin Diam, 0.0300

INTERNAL AND EXTERNAL			INTERNAL												
			Major-diameter fit							Fillet-root side fit			All fits		
					Flat-Root Side Fit										
						Major-diam fillet		Major diam							Space width
N	Pitch diam, ref	Base-circle diam, ref	Major diam, basic	*TIF* diam	Minor diam	Rad	Ht	Full deden[b]	Short deden[c]	*TIF* diam	Minor diam	Major diam	Fillet rad	Measurement between pins	Min effective 0.0327
1	3	3	4	5	6	7	8	9A	9B	10	11	12	13	14	15
Recommended tolerance→			+0.0007 + L^d −0.0000	Min	+0.0015 −0.0000	App	Max	+0.0071 −0.0000	+0.0007 + L^d −(0.0007 + L)	Min	+0.0015 −0.0000	+0.0071 −0.0000	Min[e]	Max	Dimensional Max[f]
6	0.1250	0.1083	0.1458	0.145	0.1125	0.003	0.001	0.1540	0.1458	0.1458	0.1125	0.1625	—	0.0961	0.0351
7	0.1458	0.1263	0.1667	0.165	0.1312	0.003	0.001	0.1748	0.1667	0.1667	0.1312	0.1833	—	0.1134	0.0352
8	0.1667	0.1443	0.1875	0.186	0.1458	0.004	0.001	0.1956	0.1875	0.1875	0.1458	0.2042	—	0.1378	0.0352
9	0.1875	0.1624	0.2083	0.207	0.1667	0.004	0.001	0.2165	0.2083	0.2083	0.1667	0.2250	0.001	0.1558	0.0352
10	0.2083	0.1804	0.2292	0.226	0.1875	0.004	0.002	0.2373	0.2292	0.2292	0.1875	0.2458	0.001	0.1795	0.0352
11	0.2292	0.1985	0.2500	0.247	0.2083	0.004	0.002	0.2582	0.2500	0.2500	0.2083	0.2667	0.001	0.1979	0.0352
12	0.2500	0.2165	0.2708	0.268	0.2292	0.004	0.002	0.2790	0.2708	0.2708	0.2292	0.2875	0.002	0.2211	0.0352
13	0.2708	0.2345	0.2917	0.288	0.2500	0.004	0.002	0.2998	0.2917	0.2917	0.2500	0.3083	0.002	0.2400	0.0352
14	0.2917	0.2526	0.3125	0.309	0.2708	0.004	0.002	0.3207	0.3125	0.3125	0.2708	0.3291	0.002	0.2628	0.0352
15	0.3125	0.2706	0.3333	0.330	0.2917	0.004	0.002	0.3415	0.3333	0.3333	0.2917	0.3500	0.002	0.2819	0.0352
16	0.3333	0.2887	0.3542	0.351	0.3125	0.004	0.002	0.3623	0.3542	0.3542	0.3125	0.3708	0.002	0.3045	0.0352
17	0.3542	0.3067	0.3750	0.372	0.3333	0.004	0.002	0.3832	0.3750	0.3750	0.3333	0.3917	0.003	0.3237	0.0352
18	0.3750	0.3248	0.3958	0.393	0.3542	0.004	0.002	0.4040	0.3958	0.3958	0.3542	0.4125	0.003	0.3461	0.0352
19	0.3958	0.3428	0.4167	0.413	0.3750	0.004	0.002	0.4248	0.4167	0.4167	0.3750	0.4333	0.003	0.3655	0.0352
20	0.4167	0.3608	0.4375	0.434	0.3958	0.004	0.002	0.4457	0.4375	0.4375	0.3958	0.4542	0.003	0.3877	0.0352
21	0.4375	0.3789	0.4583	0.455	0.4167	0.004	0.002	0.4665	0.4583	0.4583	0.4167	0.4750	0.003	0.4075	0.0353
22	0.4583	0.3969	0.4792	0.476	0.4375	0.004	0.002	0.4873	0.4792	0.4792	0.4375	0.4958	0.003	0.4296	0.0353
23	0.4792	0.4150	0.5000	0.497	0.4583	0.004	0.002	0.5082	0.5000	0.5000	0.4583	0.5167	0.003	0.4493	0.0353
24	0.5000	0.4330	0.5208	0.518	0.4792	0.004	0.002	0.5290	0.5208	0.5208	0.4792	0.5375	0.003	0.4712	0.0353
25	0.5208	0.4511	0.5417	0.538	0.5000	0.004	0.002	0.5498	0.5417	0.5417	0.5000	0.5583	0.003	0.4911	0.0353
26	0.5417	0.4691	0.5625	0.559	0.5208	0.004	0.002	0.5707	0.5625	0.5625	0.5208	0.5791	0.003	0.5129	0.0353
27	0.5625	0.4871	0.5833	0.580	0.5417	0.004	0.002	0.5915	0.5833	0.5833	0.5417	0.6000	0.003	0.5328	0.0353
28	0.5833	0.5052	0.6042	0.601	0.5625	0.005	0.002	0.6123	0.6042	0.6042	0.5625	0.6208	0.003	0.5546	0.0353
29	0.6042	0.5232	0.6250	0.622	0.5833	0.005	0.002	0.6332	0.6250	0.6250	0.5833	0.6417	0.003	0.5746	0.0353
30	0.6250	0.5413	0.6458	0.643	0.6042	0.005	0.002	0.6540	0.6458	0.6458	0.6042	0.6625	0.003	0.5963	0.0353
31	0.6458	0.5593	0.6667	0.664	0.6250	0.005	0.002	0.6748	0.6667	0.6667	0.6250	0.6833	0.003	0.6163	0.0353
32	0.6667	0.5774	0.6875	0.684	0.6458	0.005	0.002	0.6957	0.6875	0.6875	0.6458	0.7042	0.004	0.6379	0.0353
33	0.6875	0.5954	0.7083	0.705	0.6667	0.005	0.002	0.7165	0.7083	0.7083	0.6667	0.7250	0.004	0.6580	0.0353
34	0.7083	0.6134	0.7292	0.726	0.6875	0.005	0.002	0.7373	0.7292	0.7292	0.6875	0.7458	0.004	0.6796	0.0353
35	0.7292	0.6315	0.7500	0.747	0.7083	0.005	0.002	0.7582	0.7500	0.7500	0.7083	0.7667	0.004	0.6998	0.0354
36	0.7500	0.6495	0.7708	0.768	0.7292	0.005	0.002	0.7790	0.7708	0.7708	0.7292	0.7875	0.004	0.7214	0.0354
37	0.7708	0.6676	0.7917	0.789	0.7500	0.005	0.002	0.7998	0.7917	0.7917	0.7500	0.8083	0.004	0.7415	0.0354
38	0.7917	0.6856	0.8125	0.809	0.7708	0.005	0.002	0.8207	0.8125	0.8125	0.7708	0.8291	0.004	0.7630	0.0354
39	0.8125	0.7036	0.8333	0.830	0.7917	0.005	0.002	0.8415	0.8333	0.8333	0.7917	0.8500	0.004	0.7832	0.0354
40	0.8333	0.7217	0.8542	0.851	0.8125	0.005	0.002	0.8623	0.8542	0.8542	0.8125	0.8708	0.004	0.8047	0.0354
41	0.8542	0.7397	0.8750	0.872	0.8333	0.005	0.002	0.8832	0.8750	0.8750	0.8333	0.8917	0.004	0.8249	0.0354
42	0.8750	0.7578	0.8958	0.893	0.8542	0.005	0.002	0.9040	0.8958	0.8958	0.8542	0.9125	0.004	0.8464	0.0354
43	0.8958	0.7758	0.9167	0.914	0.8750	0.005	0.002	0.9248	0.9167	0.9167	0.8750	0.9333	0.004	0.8666	0.0354
44	0.9167	0.7939	0.9375	0.934	0.8958	0.005	0.002	0.9457	0.9375	0.9375	0.8958	0.9542	0.004	0.8880	0.0354
45	0.9375	0.8119	0.9583	0.955	0.9167	0.005	0.002	0.9665	0.9583	0.9583	0.9167	0.9750	0.004	0.9083	0.0354
46	0.9583	0.8299	0.9792	0.976	0.9375	0.005	0.002	0.9873	0.9792	0.9792	0.9375	0.9958	0.004	0.9297	0.0354
47	0.9792	0.8480	1.0000	0.997	0.9583	0.005	0.002	1.0082	1.0000	1.0000	0.9583	1.0167	0.004	0.9500	0.0354
48	1.0000	0.8660	1.0208	1.018	0.9792	0.005	0.002	1.0290	1.0208	1.0208	0.9792	1.0375	0.004	0.9714	0.0354
49	1.0208	0.8841	1.0417	1.039	1.0000	0.005	0.002	1.0498	1.0417	1.0417	1.0000	1.0583	0.004	0.9919	0.0355
50	1.0417	0.9021	1.0625	1.059	1.0208	0.005	0.002	1.0707	1.0625	1.0625	1.0208	1.0791	0.004	1.0132	0.0355

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Intended for cutting by a generating process.
[c] If this dimension is used, the dimension in Col 24 should be decreased by twice the amount of maximum dimensional tooth clearance (see footnote a under Table 2) and the chamfer applied.
[d] L = 0.0001 × diameter (Col 4).
[e] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[f] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the maximum space width. When allowances for lead errors must be made, add 60% of the lead error to this dimension (see Table 27).

TABLE 19b—*48/96 Diametral Pitch, External*[a]

48/96 Diametral Pitch Pressure Angle, 30°	Addendum (Basic), 0.0104 Dedendum (See Sec 6)	Circular Pitch, 0.0654 Meas-Pin Diam, 0.0400

EXTERNAL

N	Major-diameter fit[b]									Fillet root[c]		Dimensions for all fits							
	Major diameter			Major-diam chamfer		Flat-root side fit			Major diam[d]	Minor diam	Fil rad	*TIF* Diam	Measurement over pins			Tooth thickness		
						Minor diam	Minor-diam fillet									Cl A	Cl B	Cl C
																Max effective		
	Cl I	Cl II	Cl III	Dim	Ht		Rad	Ht					Cl A	Cl B	Cl C	0.0322	0.0336	0.0357
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Rec tol	+0.0000 −(0.0019 + J[e])	+0.0000 −(0.0006 + J[e])	+0.0009 + J[e] −0.0000	App	Min	+0.0000 −0.0071	App	Max	+0.0000 −0.0030	+0.0000 −0.0071	Min[f]	Max	Min	Min	Min	Min dimensional[g]		
6	0.1443	0.1457	0.1466	0.005	0.002	0.0960	0.004	0.004	0.1458	0.0833	—	0.1125	0.1808	0.1826	0.1854	0.0297	0.0311	0.0332
7	0.1652	0.1666	0.1675	0.005	0.002	0.1168	0.003	0.003	0.1667	0.1042	—	0.1312	0.1978	0.1996	0.2024	0.0297	0.0311	0.0332
8	0.1860	0.1874	0.1883	0.005	0.002	0.1377	0.003	0.003	0.1875	0.1250	—	0.1458	0.2229	0.2248	0.2277	0.0297	0.0311	0.0332
9	0.2068	0.2082	0.2091	0.005	0.002	0.1585	0.003	0.003	0.2083	0.1458	—	0.1667	0.2408	0.2427	0.2456	0.0297	0.0311	0.0332
10	0.2277	0.2291	0.2300	0.005	0.002	0.1793	0.003	0.002	0.2292	0.1667	—	0.1875	0.2646	0.2666	0.2696	0.0296	0.0310	0.0331
11	0.2485	0.2499	0.2508	0.005	0.002	0.2002	0.002	0.002	0.2500	0.1875	0.007	0.2083	0.2831	0.2851	0.2881	0.0296	0.0310	0.0331
12	0.2693	0.2707	0.2716	0.005	0.002	0.2210	0.002	0.002	0.2708	0.2083	0.006	0.2292	0.3065	0.3086	0.3116	0.0296	0.0310	0.0331
13	0.2902	0.2916	0.2925	0.005	0.002	0.2418	0.002	0.002	0.2917	0.2292	0.006	0.2500	0.3254	0.3274	0.3305	0.0296	0.0310	0.0331
14	0.3110	0.3124	0.3133	0.005	0.002	0.2627	0.002	0.002	0.3125	0.2500	0.006	0.2708	0.3484	0.3504	0.3535	0.0296	0.0310	0.0331
15	0.3318	0.3332	0.3341	0.005	0.002	0.2835	0.002	0.002	0.3333	0.2708	0.006	0.2917	0.3675	0.3696	0.3727	0.0296	0.0310	0.0331
16	0.3527	0.3541	0.3550	0.005	0.002	0.3043	0.002	0.002	0.3542	0.2917	0.006	0.3125	0.3902	0.3923	0.3954	0.0296	0.0310	0.0331
17	0.3735	0.3749	0.3758	0.005	0.002	0.3251	0.002	0.002	0.3750	0.3125	0.005	0.3333	0.4095	0.4116	0.4147	0.0296	0.0310	0.0331
18	0.3943	0.3957	0.3966	0.005	0.002	0.3460	0.002	0.002	0.3958	0.3333	0.005	0.3542	0.4319	0.4340	0.4372	0.0296	0.0310	0.0331
19	0.4152	0.4166	0.4175	0.005	0.002	0.3668	0.002	0.002	0.4167	0.3542	0.005	0.3750	0.4514	0.4535	0.4567	0.0296	0.0310	0.0331
20	0.4360	0.4374	0.4383	0.005	0.002	0.3877	0.002	0.002	0.4375	0.3750	0.005	0.3958	0.4737	0.4758	0.4790	0.0296	0.0310	0.0331
21	0.4568	0.4582	0.4591	0.005	0.002	0.4085	0.002	0.002	0.4583	0.3958	0.005	0.4167	0.4933	0.4954	0.4986	0.0296	0.0310	0.0331
22	0.4777	0.4791	0.4800	0.005	0.002	0.4293	0.002	0.002	0.4792	0.4167	0.005	0.4375	0.5154	0.5176	0.5208	0.0296	0.0310	0.0331
23	0.4985	0.4999	0.5009	0.005	0.002	0.4502	0.002	0.002	0.5000	0.4375	0.005	0.4583	0.5351	0.5373	0.5405	0.0296	0.0310	0.0331
24	0.5193	0.5207	0.5217	0.005	0.002	0.4710	0.002	0.002	0.5208	0.4583	0.005	0.4792	0.5572	0.5594	0.5626	0.0296	0.0310	0.0331
25	0.5402	0.5416	0.5426	0.005	0.002	0.4918	0.002	0.002	0.5417	0.4792	0.005	0.5000	0.5770	0.5792	0.5824	0.0296	0.0310	0.0331
26	0.5610	0.5624	0.5634	0.005	0.002	0.5127	0.002	0.002	0.5625	0.5000	0.005	0.5208	0.5989	0.6010	0.6043	0.0296	0.0310	0.0331
27	0.5818	0.5832	0.5842	0.005	0.002	0.5345	0.002	0.002	0.5833	0.5208	0.005	0.5417	0.6188	0.6209	0.6242	0.0296	0.0310	0.0331
28	0.6027	0.6041	0.6051	0.005	0.002	0.5543	0.002	0.002	0.6042	0.5417	0.004	0.5625	0.6405	0.6427	0.6460	0.0295	0.0309	0.0330
29	0.6235	0.6249	0.6259	0.005	0.002	0.5751	0.002	0.002	0.6250	0.5625	0.004	0.5833	0.6604	0.6626	0.6659	0.0295	0.0309	0.0330
30	0.6443	0.6457	0.6467	0.005	0.002	0.5960	0.002	0.002	0.6458	0.5833	0.004	0.6042	0.6822	0.6844	0.6877	0.0295	0.0309	0.0330
31	0.6652	0.6666	0.6676	0.005	0.002	0.6168	0.002	0.002	0.6667	0.6042	0.004	0.6250	0.7021	0.7044	0.7077	0.0295	0.0309	0.0330
32	0.6860	0.6874	0.6884	0.005	0.002	0.6377	0.002	0.002	0.6875	0.6250	0.004	0.6458	0.7238	0.7260	0.7294	0.0295	0.0309	0.0330
33	0.7068	0.7082	0.7092	0.005	0.002	0.6585	0.002	0.002	0.7083	0.6458	0.004	0.6667	0.7439	0.7461	0.7495	0.0295	0.0309	0.0330
34	0.7277	0.7291	0.7301	0.005	0.002	0.6793	0.002	0.002	0.7292	0.6667	0.004	0.6875	0.7656	0.7678	0.7712	0.0295	0.0309	0.0330
35	0.7485	0.7499	0.7509	0.005	0.002	0.7002	0.002	0.001	0.7500	0.6875	0.004	0.7083	0.7857	0.7879	0.7913	0.0295	0.0309	0.0330
36	0.7693	0.7707	0.7717	0.005	0.002	0.7210	0.002	0.001	0.7708	0.7083	0.004	0.7292	0.8073	0.8095	0.8129	0.0295	0.0309	0.0330
37	0.7902	0.7916	0.7926	0.005	0.002	0.7418	0.002	0.001	0.7917	0.7292	0.004	0.7500	0.8274	0.8296	0.8330	0.0295	0.0309	0.0330
38	0.8110	0.8124	0.8134	0.005	0.002	0.7627	0.002	0.001	0.8125	0.7500	0.004	0.7708	0.8490	0.8512	0.8546	0.0295	0.0309	0.0330
39	0.8318	0.8332	0.8342	0.005	0.002	0.7835	0.002	0.001	0.8333	0.7708	0.004	0.7917	0.8692	0.8714	0.8748	0.0295	0.0309	0.0330
40	0.8527	0.8541	0.8551	0.005	0.002	0.8043	0.002	0.001	0.8542	0.7917	0.004	0.8125	0.8906	0.8929	0.8963	0.0295	0.0309	0.0330
41	0.8735	0.8749	0.8759	0.005	0.002	0.8251	0.002	0.001	0.8750	0.8125	0.004	0.8333	0.9108	0.9131	0.9165	0.0295	0.0309	0.0330
42	0.8943	0.8957	0.8967	0.005	0.002	0.8460	0.002	0.001	0.8958	0.8333	0.004	0.8542	0.9323	0.9346	0.9380	0.0295	0.0309	0.0330
43	0.9152	0.9166	0.9176	0.005	0.002	0.8668	0.002	0.001	0.9167	0.8542	0.004	0.8750	0.9525	0.9548	0.9582	0.0295	0.0309	0.0330
44	0.9360	0.9374	0.9384	0.005	0.002	0.8877	0.002	0.001	0.9375	0.8750	0.004	0.8958	0.9740	0.9762	0.9797	0.0295	0.0309	0.0330
45	0.9568	0.9582	0.9592	0.005	0.002	0.9085	0.002	0.001	0.9583	0.8958	0.004	0.9167	0.9943	0.9966	1.0000	0.0295	0.0309	0.0330
46	0.9777	0.9791	0.9801	0.005	0.002	0.9293	0.002	0.001	0.9792	0.9167	0.004	0.9375	1.0157	1.0180	1.0214	0.0295	0.0309	0.0330
47	0.9985	0.9999	1.0009	0.005	0.002	0.9502	0.002	0.001	1.0000	0.9375	0.004	0.9583	1.0358	1.0381	1.0415	0.0294	0.0308	0.0329
48	1.0193	1.0207	1.0217	0.005	0.002	0.9710	0.002	0.001	1.0208	0.9583	0.004	0.9792	1.0572	1.0595	1.0629	0.0294	0.0308	0.0329
49	1.0402	1.0416	1.0426	0.005	0.002	0.9918	0.002	0.001	1.0417	0.9792	0.004	1.0000	1.0775	1.0798	1.0832	0.0294	0.0308	0.0329
50	1.0610	1.0624	1.0634	0.005	0.002	1.0127	0.002	0.001	1.0625	1.0000	0.004	1.0208	1.0989	1.1012	1.1046	0.0294	0.0308	0.0329

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Measurement over pins for Class A is recommended (Col 28), but if tighter fits are required, Class B (Col 29) may be used. See also Sections 19, 26, and 27.
[c] This may be used for a major-diameter fit by using dimension in Col 16, 17, or 18 instead of that in Col 24.
[d] When Col 9B is used for the internal spline, reduce this dimension as covered in Table 19a, footnote c.
[e] J = 0.0002 × diameter (Col 24).
[f] Represents minimum allowable radius of curvature, and is based on 75% of the full tangent radius for maximum depth.
[g] Allowable errors (Table 27), except lead, have been added to the machining tolerance in computing the minimum tooth thickness. When allowances for lead errors must be made, subtract 60% of the lead error from this dimension (see Table 27).

TABLE 20—*5/10 Diametral Pitch, Minor-Diameter Fits*[a]

5/10 Diametral Pitch Pressure Angle, 30°	Addendum[b] (Basic), 0.1000 Meas-Pin Diam (Int), 0.2880	Circular Pitch, 0.6283 Meas-Pin Diam (Ext), 0.3840

MINOR-DIAMETER FITS[c]

Internal and External			Internal										External					
N	Pitch diam, ref	Base-circle diam	*TIF* diam	Major-diam fillet		Major diam	Minor-diam chamfer		Minor diameter			Measurement between pins	Major diam	Minor diam, basic	Minor-diam fillet		*TIF* diam	Measurement over pins
				Rad	Ht		Ang	Ht	Cl X	Cl Y	Cl Z				Rad	Ht		
1	2	3	10	7	8	9-A	34	35	36	37	38	14	24	39	22	23	40	28
Recommended tolerance→			Min	App	Max	+0.0250 −0.0000	Deg	Min	+0.0019 + L^d −0.0000	+0.0006 + L^d −0.0000	+0.0000 −(0.0009 + L^d)	Max	+0.0000 −0.0070	+0.0000 −(0.0006 + J^e)	App	Max	Max	Min[f]
6	1.2000	1.0392	1.4000	0.029	0.010	1.4440	53.5	0.040	1.0015	1.0001	0.9991	0.8859	1.4000	1.0000	0.034	0.034	1.067	1.7676
7	1.4000	1.2124	1.6000	0.032	0.012	1.6440	53.5	0.036	1.2015	1.2001	1.1991	1.0505	1.6000	1.2000	0.030	0.030	1.259	1.9307
8	1.6000	1.3856	1.8000	0.034	0.013	1.8440	53.5	0.033	1.4015	1.4001	1.3990	1.2861	1.8000	1.4000	0.028	0.027	1.453	2.1729
9	1.8000	1.5588	2.0000	0.036	0.014	2.0440	53.5	0.030	1.6015	1.6001	1.5990	1.4593	2.0000	1.6000	0.026	0.025	1.649	2.3447
10	2.0000	1.7321	2.2000	0.037	0.015	2.2440	53.5	0.029	1.8015	1.8001	1.7989	1.6862	2.2000	1.8000	0.024	0.024	1.847	2.5767
11	2.2000	1.9053	2.4000	0.038	0.016	2.4440	53.5	0.027	2.0015	2.0001	1.9989	1.8641	2.4000	2.0000	0.023	0.023	2.045	2.7539
12	2.4000	2.0785	2.6000	0.039	0.016	2.6440	53.5	0.026	2.2015	2.2001	2.1989	2.0864	2.6000	2.2000	0.022	0.021	2.241	2.9796
13	2.6000	2.2517	2.8000	0.039	0.017	2.8440	53.5	0.025	2.4015	2.4001	2.3988	2.2676	2.8000	2.4000	0.022	0.021	2.441	3.1604
14	2.8000	2.4249	3.0000	0.040	0.017	3.0440	53.5	0.024	2.6015	2.6001	2.5988	2.4864	3.0000	2.6000	0.021	0.020	2.639	3.3817
15	3.0000	2.5981	3.2000	0.040	0.018	3.2440	53.5	0.023	2.8015	2.8001	2.7987	2.6701	3.2000	2.8000	0.020	0.019	2.837	3.5652
16	3.2000	2.7713	3.4000	0.041	0.018	3.4440	53.5	0.022	3.0015	3.0001	2.9987	2.8866	3.4000	3.0000	0.020	0.019	3.037	3.7835
17	3.4000	2.9445	3.6000	0.041	0.018	3.6440	53.5	0.022	3.2015	3.2001	3.1987	3.0722	3.6000	3.2000	0.020	0.018	3.235	3.9690
18	3.6000	3.1177	3.8000	0.041	0.019	3.8440	53.5	0.021	3.4015	3.4001	3.3986	3.2866	3.8000	3.4000	0.020	0.018	3.435	4.1851
19	3.8000	3.2909	4.0000	0.042	0.019	4.0440	53.5	0.021	3.6015	3.6001	3.5986	3.4738	4.0000	3.6000	0.020	0.017	3.633	4.3720
20	4.0000	3.4641	4.2000	0.042	0.019	4.2440	53.5	0.020	3.8015	3.8001	3.7985	3.6866	4.2000	3.8000	0.020	0.017	3.833	4.5863
21	4.2000	3.6373	4.4000	0.042	0.019	4.4440	53.5	0.020	4.0015	4.0001	3.9985	3.8750	4.4000	4.0000	0.020	0.017	4.033	4.7742
22	4.4000	3.8105	4.6000	0.042	0.019	4.6440	53.5	0.020	4.2015	4.2001	4.1985	4.0867	4.6000	4.2000	0.020	0.016	4.231	4.9872
23	4.6000	3.9837	4.8000	0.042	0.019	4.8440	52.5	0.019	4.4015	4.4001	4.3984	4.2760	4.8000	4.4000	0.020	0.016	4.431	5.1765
24	4.8000	4.1569	5.0000	0.043	0.020	5.0440	53.5	0.019	4.6015	4.6001	4.5984	4.4867	5.0000	4.6000	0.020	0.016	4.631	5.3880
25	5.0000	4.3301	5.2000	0.043	0.020	5.2440	53.5	0.019	4.8015	4.8001	4.7983	4.6769	5.2000	4.8000	0.020	0.016	4.830	5.5782
26	5.2000	4.5033	5.4000	0.043	0.020	5.4440	53.5	0.019	5.0015	5.0001	4.9983	4.8867	5.4000	5.0000	0.020	0.016	5.030	5.7889
27	5.4000	4.6765	5.6000	0.043	0.020	5.6440	53.5	0.018	5.2015	5.2001	5.1983	5.0778	5.6000	5.2000	0.020	0.015	5.228	5.9797
28	5.6000	4.8497	5.8000	0.043	0.020	5.8440	53.5	0.018	5.4015	5.4001	5.3982	5.2870	5.8000	5.4000	0.020	0.015	5.428	6.1895
29	5.8000	5.0229	6.0000	0.043	0.020	6.0440	53.5	0.018	5.6015	5.6001	5.5982	5.4784	6.0000	5.6000	0.020	0.015	5.628	6.3810
30	6.0000	5.1962	6.2000	0.043	0.020	6.2440	53.5	0.018	5.8015	5.8001	5.7981	5.6869	6.2000	5.8000	0.020	0.015	5.828	6.5901
31	6.2000	5.3694	6.4000	0.044	0.020	6.4440	53.5	0.018	6.0015	6.0001	5.9981	5.8790	6.4000	6.0000	0.020	0.015	6.028	6.7822
32	6.4000	5.5426	6.6000	0.044	0.021	6.6440	53.5	0.018	6.2015	6.2001	6.1981	6.0869	6.6000	6.2000	0.020	0.015	6.228	6.9907
33	6.6000	5.7158	6.8000	0.044	0.021	6.8440	53.5	0.017	6.4015	6.4001	6.3980	6.2795	6.8000	6.4000	0.020	0.014	6.426	7.1832
34	6.8000	5.8890	7.0000	0.044	0.021	7.0440	53.5	0.017	6.6015	6.6001	6.5980	6.4869	7.0000	6.6000	0.020	0.014	6.626	7.3911
35	7.0000	6.0622	7.2000	0.044	0.021	7.2440	53.5	0.017	6.8015	6.8001	6.7979	6.6799	7.2000	6.8000	0.020	0.014	6.826	7.5840
36	7.2000	6.2354	7.4000	0.044	0.021	7.4440	53.5	0.017	7.0015	7.0001	6.9979	6.8869	7.4000	7.0000	0.020	0.014	7.026	7.7914
37	7.4000	6.4086	7.6000	0.044	0.021	7.6440	53.5	0.017	7.2015	7.2001	7.1979	7.0805	7.6000	7.2000	0.020	0.014	7.226	7.9847
38	7.6000	6.5818	7.8000	0.044	0.021	7.8440	54.0	0.017	7.4015	7.4001	7.3978	7.2871	7.8000	7.4000	0.020	0.014	7.426	8.1918
39	7.8000	6.7550	8.0000	0.044	0.021	8.0440	54.0	0.017	7.6015	7.6001	7.5978	7.4808	8.0000	7.6000	0.020	0.014	7.626	8.3855
40	8.0000	6.9282	8.2000	0.044	0.021	8.2440	54.0	0.017	7.8015	7.8001	7.7977	7.6871	8.2000	7.8000	0.020	0.014	7.826	8.5922
41	8.2000	7.1014	8.4000	0.044	0.021	8.4440	54.0	0.017	8.0015	8.0001	7.9977	7.8812	8.4000	8.0000	0.020	0.014	8.026	8.7862
42	8.4000	7.2746	8.6000	0.044	0.021	8.6440	54.0	0.016	8.2015	8.2001	8.1977	8.0871	8.6000	8.2000	0.020	0.014	8.226	8.9925
43	8.6000	7.4478	8.8000	0.044	0.021	8.8440	54.0	0.016	8.4015	8.4001	8.3976	8.2814	8.8000	8.4000	0.020	0.014	8.426	9.1868
44	8.8000	7.6210	9.0000	0.044	0.021	9.0440	54.0	0.016	8.6015	8.6001	8.5976	8.4872	9.0000	8.6000	0.020	0.014	8.626	9.3928
45	9.0000	7.7942	9.2000	0.044	0.021	9 2440	54.0	0.016	8.8015	8.8001	8.7975	8.6817	9.2000	8.8000	0.020	0.013	8.824	9.5873
46	9.2000	7.9674	9.4000	0.044	0.021	9.4440	54.0	0.016	9.0015	9.0001	8.9975	8.8872	9.4000	9.0000	0.020	0.013	9.024	9.7931
47	9.4000	8.1406	9.6000	0.045	0.021	9.6440	54.0	0.016	9.2015	9.2001	9.1975	9.0820	9.6000	9.2000	0.020	0.013	9.224	9.9878
48	9.6000	8.3138	9.8000	0.045	0.021	9.8440	54.0	0.016	9.4015	9.4001	9.3974	9.2873	9.8000	9.4000	0.020	0.013	9.424	10.1933
49	9.8000	8.4870	10.0000	0.045	0.021	10.0440	54.0	0.016	9.6015	9.6001	9.5974	9.4823	10.0000	9.6000	0.020	0.013	9.624	10.3881
50	10.0000	8.6603	10.2000	0.045	0.021	10.2440	54.0	0.016	9.8015	9.8001	9.7973	9.6873	10.2000	9.8000	0.020	0.013	9.823	10.5934

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] For dedendum, see Section 6. Dedendum of external spline is the same as the addendum.
[c] For space width and tooth thickness, see Tables 9a and 9b.
[d] L = 0.0001 × diameter (Col 39).
[e] J = 0.0002 × diameter (Col 39).
[f] If tighter fits are desired, use Col 29 or 30, Table 9b.

TABLE 21—*6/12 Diametral Pitch, Minor-Diameter Fits*[a]

6/12 Diametral Pitch
Pressure Angle, 30°

Addendum[b] (Basic), 0.0833
Meas-Pin Diam (Int), 0.2400

Circular Pitch, 0.5236
Meas-Pin Diam (Ext), 0.3200

MINOR-DIAMETER FITS[c]

Internal and External			Internal										External					
N	Pitch diam, ref	Base-circle diam	TIF diam	Major-diam fillet		Major diam	Minor-diam chamfer		Minor diameter			Measurement between pins	Major diam	Minor diam, basic	Minor-diam fillet		TIF diam	Measurement over pins
				Rad	Ht		Ang	Ht	Cl X	Cl Y	Cl Z				Rad	Ht		
1	2	3	10	7	8	9-A	34	35	36	37	38	14	24	39	22	23	40	28
Recommended tolerance⟶			Min	App	Max	$+0.0217$ -0.0000	Deg	Min	$+0.0019$ $+ L^d$ -0.0000	$+0.0006$ $+ L^d$ -0.0000	$+0.0000$ $-(0.0009$ $+ L^d)$	Max	$+0.0000$ -0.0070	$+0.0000$ $-(0.0006$ $+ J^e)$	App	Max	Max	Min[f]
6	1.0000	0.8660	1.1667	0.024	0.009	1.2040	53.5	0.034	0.8348	0.8334	0.8324	0.7379	1.1667	0.8333	0.028	0.028	0.889	1.4730
7	1.1667	1.0104	1.3333	0.027	0.010	1.3707	53.5	0.030	1.0015	1.0001	0.9991	0.8762	1.3333	1.0000	0.025	0.025	1.049	1.6090
8	1.3333	1.1547	1.5000	0.028	0.011	1.5373	53.5	0.027	1.1682	1.1668	1.1658	1.0716	1.5000	1.1667	0.023	0.023	1.212	1.8108
9	1.5000	1.2990	1.6667	0.030	0.012	1.7040	53.5	0.025	1.3348	1.3334	1.3323	1.2159	1.6667	1.3333	0.022	0.021	1.374	1.9540
10	1.6667	1.4434	1.8333	0.031	0.013	1.8707	53.5	0.024	1.5015	1.5001	1.4990	1.4051	1.8333	1.5000	0.020	0.020	1.539	2.1472
11	1.8333	1.5877	2.0000	0.032	0.013	2.0373	53.5	0.023	1.6682	1.6668	1.6657	1.5534	2.0000	1.6667	0.019	0.019	1.704	2.2949
12	2.0000	1.7321	2.1667	0.032	0.014	2.2040	53.5	0.022	1.8348	1.8334	1.8322	1.7385	2.1667	1.8333	0.018	0.018	1.868	2.4830
13	2.1667	1.8764	2.3333	0.033	0.014	2.3707	53.5	0.021	2.0015	2.0001	1.9989	1.8895	2.3333	2.0000	0.018	0.017	2.033	2.6336
14	2.3333	2.0207	2.5000	0.033	0.014	2.5373	53.5	0.020	2.1682	2.1668	2.1656	2.0719	2.5000	2.1667	0.018	0.017	2.200	2.8181
15	2.5000	2.1651	2.6667	0.034	0.015	2.7040	53.5	0.019	2.3348	2.3334	2.3321	2.2250	2.6667	2.3333	0.017	0.016	2.364	2.9710
16	2.6667	2.3094	2.8333	0.034	0.015	2 8707	53.5	0.019	2.5015	2.5001	2.4988	2.4052	2.8333	2.5000	0.017	0.016	2.531	3.1530
17	2.8333	2.4537	3.0000	0.034	0.015	3.0373	53.5	0.018	2.6682	2.6668	2.6655	2.5599	3.0000	2.6667	0.017	0.015	2.696	3.3075
18	3.0000	2.5981	3.1667	0.035	0.016	3.2040	53.5	0.018	2.8348	2.8334	2.8320	2.7386	3.1667	2.8333	0.017	0.015	2.862	3.4875
19	3.1667	2.7424	3.3333	0.035	0.016	3.3707	53.5	0.017	3.0015	3.0001	2.9987	2.8946	3.3333	3.0000	0.017	0.015	3.029	3.6433
20	3.3333	2.8868	3.5000	0.035	0.016	3.5373	53.5	0.017	3.1682	3.1668	3.1654	3.0720	3.5000	3.1667	0.017	0.014	3.194	3.8219
21	3.5000	3.0311	3.6667	0.035	0.016	3.7040	53.5	0.017	3.3348	3.3334	3.3319	3.2291	3.6667	3.3333	0.017	0.014	3.360	3.9788
22	3.6667	3.1754	3.8333	0.035	0.016	3.8707	53.5	0.016	3.5015	3.5001	3.4986	3.4055	3.8333	3.5000	0.017	0.014	3.527	4.1560
23	3.8333	3.3198	4.0000	0.035	0.016	4.0373	53.5	0.016	3.6682	3.6668	3.6653	3.5633	4.0000	3.6667	0.017	0.014	3.693	4.3138
24	4.0000	3.4641	4.1667	0.036	0.016	4.2040	53.5	0.016	3.8348	3.8334	3.8318	3.7389	4.1667	3.8333	0.017	0.013	3.858	4.4902
25	4.1667	3.6084	4.3333	0.036	0.017	4.3707	53.5	0.016	4.0015	4.0001	3.9985	3.8973	4.3333	4.0000	0.017	0.013	4.025	4.6486
26	4.3333	3.7528	4.5000	0.036	0.017	4.5373	53.5	0.016	4.1682	4.1668	4.1652	4.0721	4.5000	4.1667	0.017	0.013	4.191	4.8241
27	4.5000	3.8971	4.6667	0.036	0.017	4.7040	53.5	0.015	4.3348	4.3334	4.3317	4.2312	4.6667	4.3333	0.017	0.013	4.358	4.9832
28	4.6667	4.0415	4.8333	0.036	0.017	4.8707	53.5	0.015	4.5015	4.5001	4.4984	4.4055	4.8333	4.5000	0.017	0.013	4.525	5.1578
29	4.8333	4.1858	5.0000	0.036	0.017	5.0373	53.5	0.015	4.6682	4.6668	4.6651	4.5651	5.0000	4.6667	0.017	0.013	4.691	5.3174
30	5.0000	4.3301	5.1667	0.036	0.017	5.2040	53.5	0.015	4.8348	4.8334	4.8316	4.7388	5.1667	4.8333	0.017	0.012	4.856	5.4917
31	5.1667	4.4745	5.3333	0.036	0.017	5.3707	53.5	0.015	5.0015	5.0001	4.9983	4.8989	5.3333	5.0000	0.017	0.012	5.022	5.6518
32	5.3333	4.6188	5.5000	0.036	0.017	5.5373	53.5	0.015	5.1682	5.1668	5.1650	5.0722	5.5000	5.1667	0.017	0.012	5.189	5.8255
33	5.5000	4.7631	5.6667	0.037	0.017	5.7040	53.5	0.015	5.3348	5.3334	5.3315	5.2327	5.6667	5.3333	0.017	0.012	5.356	5.9860
34	5.6667	4.9075	5.8333	0.037	0.017	5.8707	53.5	0.014	5.5015	5.5001	5.4982	5.4055	5.8333	5.5000	0.017	0.012	5.522	6.1592
35	5.8333	5.0518	6.0000	0.037	0.017	6.0373	53.5	0.014	5.6682	5.6668	5.6649	5.5666	6.0000	5.6667	0.017	0.012	5.689	6.3200
36	6.0000	5.1962	6.1667	0.037	0.017	6.2040	53.5	0.014	5.8348	5.8334	5.8314	5.7391	6.1667	5.8333	0.017	0.012	5.856	6.4929
37	6.1667	5.3405	6.3333	0.037	0.017	6.3707	53.5	0.014	6.0015	6.0001	5.9981	5.9002	6.3333	6.0000	0.017	0.012	6.022	6.6540
38	6.3333	5.4848	6.5000	0.037	0.018	6.5373	54.0	0.014	6.1682	6.1668	6.1648	6.0724	6.5000	6.1667	0.017	0.012	6.189	6.8266
39	6.5000	5.6292	6.6667	0.037	0.018	6.7040	54.0	0.014	6.3348	6.3334	6.3313	6.2338	6.6667	6.3333	0.017	0.012	6.355	6.9980
40	6.6667	5.7735	6.8333	0.037	0.018	6.8707	54.0	0.014	6.5015	6.5001	6.4980	6.4058	6.8333	6.5000	0.017	0.012	6.522	7.1602
41	6.8333	5.9178	7.0000	0.037	0.018	7.0373	54.0	0.014	6.6682	6.6668	6.6647	6.5674	7.0000	6.6667	0.017	0.012	6.689	7.3219
42	7.0000	6.0622	7.1667	0.037	0.018	7.3707	54.0	0.014	6.8348	6.8334	6.8312	6.7391	7.1667	6.8333	0.017	0.011	6.853	7.4938
43	7.1667	6.2065	7.3333	0.037	0.018	7.5373	54.0	0.014	7.0015	7.0001	6.9979	6.9010	7.3333	7.0000	0.017	0.011	7.020	7.6558
44	7.3333	6.3509	7.5000	0.037	0.018	7.7040	54.0	0.014	7.1682	7.1668	7.1646	7.0724	7.5000	7.1667	0.017	0.011	7.187	7.8274
45	7.5000	6.4952	7.6667	0.037	0.018	7.8707	54.0	0.014	7.3348	7.3334	7.3311	7.2346	7.6667	7.3333	0.017	0.011	7.353	7.9895
46	7.6667	6.6395	7.8333	0.037	0.018	8.0373	54.0	0.013	7.5015	7.5001	7.4978	7.4058	7.8333	7.5000	0.017	0.011	7.520	8.1609
47	7.8333	6.7839	8.0000	0.037	0.018	8.3707	54.0	0.013	7.6682	7.6668	7.6645	7.5681	8.0000	7.6667	0.017	0.011	7.687	8.3231
48	8.0000	6.9282	8.1667	0.037	0.018	8.5373	54.0	0.013	7.8348	7.8334	7.8310	7.7391	8.1667	7.8333	0.017	0.011	7.853	8.4944
49	8.1667	7.0725	8.3333	0.037	0.018	8.7040	54.0	0.013	8.0015	8.0001	7.9977	7.9017	8.3333	8.0000	0.017	0.011	8.020	8.6569
50	8.3333	7.2169	8.5000	0.037	0.018	8.8707	54.0	0.013	8.1682	8.1668	8.1644	8.0726	8.5000	8.1667	0.017	0.011	8.187	8.8279

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] For dedendum, see Section 6. Dedendum of external spline is the same as the addendum.
[c] For space width and tooth thickness, see Tables 10a and 10b.
[d] $L = 0.0001 \times$ diameter(Col 39).
[e] $J = 0.0002 \times$ diameter (Col 39).
[f] If tighter fits are desired, use Col 29 or 30, Table 10b.

TABLE 22—*8/16 Diametral Pitch, Minor-Diameter Fits*[a]

8/16 Diametral Pitch Pressure Angle, 30°	Addendum[b] (Basic), 0.0625 Meas-Pin Diam (Int), 0.1800	Circular Pitch, 0.3927 Meas-Pin Diam (Ext), 0.2400

MINOR-DIAMETER FITS[c]

Internal and External			Internal										External					
N	Pitch diam, ref	Base-circle diam	*TIF* diam	Major-diam fillet		Major diam	Minor-diam chamfer		Minor diameter			Measurement between pins	Major diam	Minor diam, basic	Minor-diam fillet		*TIF* diam	Measurement over pins
				Rad	Ht		Ang	Ht	Cl X	Cl Y	Cl Z				Rad	Ht		
1	2	3	10	7	8	9-A	34	35	36	37	38	14	24	39	22	23	40	28
Recommended tolerance—→			Min	App	Max	+0.0175 −0.0000	Deg	Min	+0.0019 + L^d −0.0000	+0.0006 + L^d −0.0000	+0.0000 −(0.0009 + L^d)	Max	+0.0000 −0.0070	+0.0000 −(0.0006 + J^e)	App	Max	Max	Min[f]
6	0.7500	0.6495	0.8750	0.018	0.007	0.9040	53.5	0.025	0.6265	0.6251	0.6242	0.5549	0.8750	0.6250	0.021	0.021	0.666	1.1036
7	0.8750	0.7578	1.0000	0.020	0.008	1.0290	53.5	0.022	0.7515	0.7501	0.7491	0.6586	1.0000	0.7500	0.019	0.019	0.787	1.2055
8	1.0000	0.8660	1.1250	0.021	0.008	1.1540	53.5	0.020	0.8765	0.8751	0.8741	0.8051	1.1250	0.8750	0.018	0.017	0.908	1.3569
9	1.1250	0.9743	1.2500	0.022	0.009	1.2790	53.5	0.019	1.0015	1.0001	0.9991	0.9133	1.2500	1.0000	0.016	0.016	1.031	1.4643
10	1.2500	1.0825	1.3750	0.023	0.009	1.4040	53.5	0.018	1.1265	1.1251	1.1241	1.0553	1.3750	1.1250	0.015	0.015	1.154	1.6091
11	1.3750	1.1908	1.5000	0.024	0.010	1.5290	53.5	0.017	1.2515	1.2501	1.2490	1.1664	1.5000	1.2500	0.015	0.014	1.277	1.7198
12	1.5000	1.2990	1.6250	0.024	0.010	1.6540	53.5	0.016	1.3765	1.3751	1.3740	1.3053	1.6250	1.3750	0.014	0.013	1.400	1.8609
13	1.6250	1.4073	1.7500	0.024	0.010	1.7790	53.5	0.016	1.5015	1.5001	1.4990	1.4185	1.7500	1.5000	0.014	0.013	1.525	1.9739
14	1.7500	1.5156	1.8750	0.025	0.011	1.9040	53.5	0.015	1.6265	1.6251	1.6240	1.5553	1.8750	1.6250	0.013	0.012	1.648	2.1123
15	1.8750	1.6238	2.0000	0.025	0.011	2.0290	53.5	0.014	1.7515	1.7501	1.7489	1.6701	2.0000	1.7500	0.013	0.012	1.773	2.2269
16	2.0000	1.7321	2.1250	0.025	0.011	2.1540	53.5	0.014	1.8765	1.8751	1.8739	1.8053	2.1250	1.8750	0.013	0.011	1.896	2.3633
17	2.1250	1.8403	2.2500	0.026	0.011	2.2790	53.5	0.014	2.0015	2.0001	1.9989	1.9213	2.2500	2.0000	0.013	0.011	2.021	2.4792
18	2.2500	1.9486	2.3750	0.026	0.012	2.4040	53.5	0.013	2.1265	2.1251	2.1239	2.0553	2.3750	2.1250	0.013	0.011	2.146	2.6142
19	2.3750	2.0568	2.5000	0.026	0.012	2.5290	53.5	0.013	2.2515	2.2501	2.2488	2.1723	2.5000	2.2500	0.013	0.011	2.271	2.7311
20	2.5000	2.1651	2.6250	0.026	0.012	2.6540	53.5	0.013	2.3765	2.3751	2.3738	2.3053	2.6250	2.3750	0.013	0.011	2.396	2.8650
21	2.6250	2.2733	2.7500	0.026	0.012	2.7790	53.5	0.013	2.5015	2.5001	2.4988	2.4233	2.7500	2.5000	0.013	0.010	2.519	2.9827
22	2.7500	2.3816	2.8750	0.026	0.012	2.9040	53.5	0.012	2.6265	2.6251	2.6238	2.5556	2.8750	2.6250	0.013	0.010	2.644	3.1156
23	2.8750	2.4898	3.0000	0.026	0.012	3.0290	53.5	0.012	2.7515	2.7501	2.7487	2.6739	3.0000	2.7500	0.013	0.010	2.769	3.2339
24	3.0000	2.5981	3.1250	0.027	0.012	3.1540	53.5	0.012	2.8765	2.8751	2.8737	2.8056	3.1250	2.8750	0.013	0.010	2.894	3.3662
25	3.1250	2.7063	3.2500	0.027	0.012	3.2790	53.5	0.012	3.0015	3.0001	2.9987	2.9244	3.2500	3.0000	0.013	0.010	3.019	3.4850
26	3.2500	2.8146	3.3750	0.027	0.012	3.4040	53.5	0.012	3.1265	3.1251	3.1237	3.0555	3.3750	3.1250	0.013	0.010	3.144	3.6166
27	3.3750	2.9228	3.5000	0.027	0.013	3.5290	53.5	0.011	3.2515	3.2501	3.2486	3.1748	3.5000	3.2500	0.013	0.010	3.269	3.7359
28	3.5000	3.0311	3.6250	0.027	0.013	3.6540	53.5	0.011	3.3765	3.3751	3.3736	3.3055	3.6250	3.3750	0.013	0.010	3.394	3.8669
29	3.6250	3.1393	3.7500	0.027	0.013	3.7790	53.5	0.011	3.5015	3.5001	3.4986	3.4252	3.7500	3.5000	0.013	0.009	3.517	3.9866
30	3.7500	3.2476	3.8750	0.027	0.013	3.9040	53.5	0.011	3.6265	3.6251	3.6236	3.5555	3.8750	3.6250	0.013	0.009	3.642	4.1173
31	3.8750	3.3559	4.0000	0.027	0.013	4.0290	53.5	0.011	3.7515	3.7501	3.7485	3.6756	4.0000	3.7500	0.013	0.009	3.767	4.2373
32	4.0000	3.4641	4.1250	0.027	0.013	4.1540	53.5	0.011	3.8765	3.8751	3.8735	3.8055	4.1250	3.8750	0.013	0.009	3.892	4.3676
33	4.1250	3.5724	4.2500	0.027	0.013	4.2790	53.5	0.011	4.0015	4.0001	3.9985	3.9260	4.2500	4.0000	0.013	0.009	4.017	4.4880
34	4.2500	3.6806	4.3750	0.027	0.013	4.4040	53.5	0.011	4.1265	4.1251	4.1235	4.0555	4.3750	4.1250	0.013	0.009	4.142	4.6179
35	4.3750	3.7889	4.5000	0.027	0.013	4.5290	53.5	0.011	4.2515	4.2501	4.2484	4.1764	4.5000	4.2500	0.013	0.008	4.265	4.7385
36	4.5000	3.8971	4.6250	0.027	0.013	4.6540	53.5	0.011	4.3765	4.3751	4.3734	4.3058	4.6250	4.3750	0.013	0.008	4.390	4.8681
37	4.6250	4.0054	4.7500	0.028	0.013	4.7790	53.5	0.011	4.5015	4.5001	4.4984	4.4266	4.7500	4.5000	0.013	0.008	4.515	4.9890
38	4.7500	4.1136	4.8750	0.028	0.013	4.9040	54.0	0.011	4.6265	4.6251	4.6234	4.5558	4.8750	4.6250	0.013	0.008	4.640	5.1184
39	4.8750	4.2219	5.0000	0.028	0.013	5.0290	54.0	0.010	4.7515	4.7501	4.7483	4.6768	5.0000	4.7500	0.013	0.008	4.764	5.2395
40	5.0000	4.3301	5.1250	0.028	0.013	5.1540	54.0	0.010	4.8765	4.8751	4.8733	4.8058	5.1250	4.8750	0.013	0.008	4.889	5.3687
41	5.1250	4.4384	5.2500	0.028	0.013	5.2790	54.0	0.010	5.0015	5.0001	4.9983	4.9270	5.2500	5.0000	0.013	0.008	5.014	5.4899
42	5.2500	4.5466	5.3750	0.028	0.013	5.4040	54.0	0.010	5.1265	5.1251	5.1233	5.0558	5.3750	5.1250	0.013	0.008	5.139	5.6184
43	5.3750	4.6549	5.5000	0.028	0.013	5.5290	54.0	0.010	5.2515	5.2501	5.2482	5.1772	5.5000	5.2500	0.013	0.008	5.264	5.7403
44	5.5000	4.7631	5.6250	0.028	0.013	5.6540	54.0	0.010	5.3765	5.3751	5.3732	5.3058	5.6250	5.3750	0.013	0.008	5.389	5.8690
45	5.6250	4.8714	5.7500	0.028	0.013	5.7790	54.0	0.010	5.5015	5.5001	5.4982	5.4274	5.7500	5.5000	0.013	0.008	5.514	5.9906
46	5.7500	4.9797	5.8750	0.028	0.013	5.9040	54.0	0.010	5.6265	5.6251	5.6232	5.5558	5.8750	5.6250	0.013	0.008	5.639	6.1191
47	5.8750	5.0879	6.0000	0.028	0.013	6.0290	54.0	0.010	5.7515	5.7501	5.7481	5.6775	6.0000	5.7500	0.013	0.008	5.764	6.2408
48	6.0000	5.1962	6.1250	0.028	0.013	6.1540	54.0	0.010	5.8765	5.8751	5.8731	5.8058	6.1250	5.8750	0.013	0.008	5.889	6.3692
49	6.1250	5.3044	6.2500	0.028	0.013	6.2790	54.0	0.010	6.0015	6.0001	5.9981	5.9277	6.2500	6.0000	0.013	0.008	6.014	6.4911
50	6.2500	5.4127	6.3750	0.028	0.013	6.4040	54.0	0.010	6.1265	6.1251	6.1231	6.0559	6.3750	6.1250	0.013	0.008	6.139	6.6193

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] For dedendum, see Section 6. Dedendum of external spline is the same as the addendum.
[c] For space width and tooth thickness, see Tables 11a and 11b.
[d] L = 0.0001 × diameter (Col 39).
[e] J = 0.0002 × diameter (Col 39).
[f] If tighter fits are desired, use Col 29 or 30, Table 11b.

TABLE 23—*10/20 Diametral Pitch, Minor-Diameter Fits*[a]

10/20 Diametral Pitch Pressure Angle, 30°	Addendum[b] (Basic), 0.0500 Meas-Pin Diam (Int), 0.1440	Circular Pitch, 0.3142 Meas-Pin Diam (Ext), 0.1920

MINOR-DIAMETER FITS [c]

Internal and External			Internal										External					
				Major-diam fillet			Minor-diam chamfer		Minor diameter						Minor-diam fillet			
N	Pitch diam, ref	Base-circle diam	*TIF* diam	Rad	Ht	Major diam	Ang	Ht	Cl X	Cl Y	Cl Z	Measurement between pins	Major diam	Minor diam, basic	Rad	Ht	*TIF* diam	Measurement over pins
1	2	3	10	7	8	9-A	34	35	36	37	38	14	24	39	22	23	40	28
Recommended tolerance⟶			Min	App	Max	+0.0150 −0.0000	Deg	Min	+0.0019 + L^d −0.0000	+0.0006 + L^d −0.0000	+0.0000 −(0.0009 + L^d)	Max	+0.0000 −0.0025	+0.0000 −(0.0006 + J^e)	App	Max	Max	Min[f]
6	0.6000	0.5196	0.7000	0.015	0.005	0.7240	53.5	0.020	0.5015	0.5001	0.4992	0.4439	0.7000	0.5000	0.017	0.017	0.533	0.8820
7	0.7000	0.6062	0.8000	0.016	0.006	0.8240	53.5	0.018	0.6015	0.6001	0.5992	0.5269	0.8000	0.6000	0.015	0.015	0.629	0.9636
8	0.8000	0.6928	0.9000	0.017	0.007	0.9240	53.5	0.016	0.7015	0.7001	0.6992	0.6441	0.9000	0.7000	0.014	0.014	0.727	1.0846
9	0.9000	0.7794	1.0000	0.017	0.007	1.0240	53.5	0.015	0.8015	0.8001	0.7991	0.7307	1.0000	0.8000	0.013	0.013	0.825	1.1706
10	1.0000	0.8660	1.1000	0.018	0.008	1.1240	53.5	0.014	0.9015	0.9001	0.8991	0.8443	1.1000	0.9000	0.012	0.012	0.923	1.2863
11	1.1000	0.9526	1.2000	0.019	0.008	1.2240	53.5	0.014	1.0015	1.0001	0.9991	0.9332	1.2000	1.0000	0.012	0.011	1.020	1.3749
12	1.2000	1.0392	1.3000	0.019	0.008	1.3240	53.5	0.013	1.1015	1.1001	1.0991	1.0442	1.3000	1.1000	0.011	0.011	1.121	1.4878
13	1.3000	1.1258	1.4000	0.020	0.008	1.4240	53.5	0.012	1.2015	1.2001	1.1991	1.1349	1.4000	1.2000	0.011	0.010	1.219	1.5782
14	1.4000	1.2124	1.5000	0.020	0.009	1.5240	53.5	0.012	1.3015	1.3001	1.2990	1.2443	1.5000	1.3000	0.010	0.010	1.319	1.6888
15	1.5000	1.2990	1.6000	0.020	0.009	1.6240	53.5	0.012	1.4015	1.4001	1.3990	1.3362	1.6000	1.4000	0.010	0.010	1.419	1.7805
16	1.6000	1.3856	1.7000	0.020	0.009	1.7240	53.5	0.011	1.5015	1.5001	1.4990	1.4443	1.7000	1.5000	0.010	0.009	1.517	1.8897
17	1.7000	1.4722	1.8000	0.020	0.009	1.8240	53.5	0.011	1.6015	1.6001	1.5990	1.5371	1.8000	1.6000	0.010	0.009	1.617	1.9824
18	1.8000	1.5588	1.9000	0.021	0.009	1.9240	53.5	0.011	1.7015	1.7001	1.6990	1.6444	1.9000	1.7000	0.010	0.009	1.717	2.0904
19	1.9000	1.6454	2.0000	0.021	0.009	2.0240	53.5	0.010	1.8015	1.8001	1.7989	1.7379	2.0000	1.8000	0.010	0.009	1.817	2.1839
20	2.0000	1.7321	2.1000	0.021	0.010	2.1240	53.5	0.010	1.9015	1.9001	1.8989	1.8443	2.1000	1.9000	0.010	0.009	1.917	2.2910
21	2.1000	1.8187	2.2000	0.021	0.010	2.2240	53.5	0.010	2.0015	2.0001	1.9989	1.9387	2.2000	2.0000	0.010	0.008	2.015	2.3851
22	2.2000	1.9053	2.3000	0.021	0.010	2.3240	53.5	0.010	2.1015	2.1001	2.0989	2.0445	2.3000	2.1000	0.010	0.008	2.115	2.4915
23	2.3000	1.9919	2.4000	0.021	0.010	2.4240	53.5	0.010	2.2015	2.2001	2.1989	2.1392	2.4000	2.2000	0.010	0.008	2.215	2.5862
24	2.4000	2.0785	2.5000	0.021	0.010	2.5240	53.5	0.010	2.3015	2.3001	2.2988	2.2445	2.5000	2.3000	0.010	0.008	2.315	2.6919
25	2.5000	2.1651	2.6000	0.021	0.010	2.6240	53.5	0.009	2.4015	2.4001	2.3988	2.3396	2.6000	2.4000	0.010	0.008	2.415	2.7870
26	2.6000	2.2517	2.7000	0.021	0.010	2.7240	53.5	0.009	2.5015	2.5001	2.4988	2.4445	2.7000	2.5000	0.010	0.008	2.515	2.8923
27	2.7000	2.3383	2.8000	0.021	0.010	2.8240	53.5	0.009	2.6015	2.6001	2.5988	2.5400	2.8000	2.6000	0.010	0.008	2.615	2.9878
28	2.8000	2.4249	2.9000	0.022	0.010	2.9240	53.5	0.009	2.7015	2.7001	2.6988	2.6445	2.9000	2.7000	0.010	0.008	2.715	3.0925
29	2.9000	2.5115	3.0000	0.022	0.010	3.0240	53.5	0.009	2.8015	2.8001	2.7987	2.7403	3.0000	2.8000	0.010	0.008	2.815	3.1883
30	3.0000	2.5981	3.1000	0.022	0.010	3.1240	53.5	0.009	2.9015	2.9001	2.8987	2.8445	3.1000	2.9000	0.010	0.007	2.913	3.2928
31	3.1000	2.6847	3.2000	0.022	0.010	3.2240	53.5	0.009	3.0015	3.0001	2.9987	2.9406	3.2000	3.0000	0.010	0.007	3.013	3.3889
32	3.2000	2.7713	3.3000	0.022	0.010	3.3240	53.5	0.009	3.1015	3.1001	3.0987	3.0446	3.3000	3.1000	0.010	0.007	3.113	3.4930
33	3.3000	2.8579	3.4000	0.022	0.010	3.4240	53.5	0.009	3.2015	3.2001	3.1987	3.1409	3.4000	3.2000	0.010	0.007	3.213	3.5893
34	3.4000	2.9445	3.5000	0.022	0.010	3.5240	53.5	0.009	3.3015	3.3001	3.2986	3.2446	3.5000	3.3000	0.010	0.007	3.313	3.6933
35	3.5000	3.0311	3.6000	0.022	0.010	3.6240	53.5	0.009	3.4015	3.4001	3.3986	3.3412	3.6000	3.4000	0.010	0.007	3.413	3.7898
36	3.6000	3.1177	3.7000	0.022	0.010	3.7240	53.5	0.009	3.5015	3.5001	3.4986	3.4447	3.7000	3.5000	0.010	0.007	3.513	3.8935
37	3.7000	3.2043	3.8000	0.022	0.010	3.8240	53.5	0.009	3.6015	3.6001	3.5986	3.5413	3.8000	3.6000	0.010	0.007	3.613	3.9902
38	3.8000	3.2909	3.9000	0.022	0.011	3.9240	54.0	0.008	3.7015	3.7001	3.6986	3.6447	3.9000	3.7000	0.010	0.007	3.713	4.0937
39	3.9000	3.3775	4.0000	0.022	0.011	4.0240	54.0	0.008	3.8015	3.8001	3.7985	3.7415	4.0000	3.8000	0.010	0.007	3.813	4.1906
40	4.0000	3.4641	4.1000	0.022	0.011	4.1240	54.0	0.008	3.9015	3.9001	3.8985	3.8447	4.1000	3.9000	0.010	0.007	3.913	4.2938
41	4.1000	3.5507	4.2000	0.022	0.011	4.2240	54.0	0.008	4.0015	4.0001	3.9985	3.9416	4.2000	4.0000	0.010	0.007	4.013	4.3908
42	4.2000	3.6373	4.3000	0.022	0.011	4.3240	54.0	0.008	4.1015	4.1001	4.0985	4.0447	4.3000	4.1000	0.010	0.007	4.113	4.4940
43	4.3000	3.7239	4.4000	0.022	0.011	4.4240	54.0	0.008	4.2015	4.2001	4.1985	4.1418	4.4000	4.2000	0.010	0.007	4.213	4.5911
44	4.4000	3.8105	4.5000	0.022	0.011	4.5240	54.0	0.008	4.3015	4.3001	4.2984	4.2447	4.5000	4.3000	0.010	0.007	4.313	4.6941
45	4.5000	3.8971	4.6000	0.022	0.011	4.6240	54.0	0.008	4.4015	4.4001	4.3984	4.3420	4.6000	4.4000	0.010	0.007	4.413	4.7914
46	4.6000	3.9837	4.7000	0.022	0.011	4.7240	54.0	0.008	4.5015	4.5001	4.4984	4.4447	4.7000	4.5000	0.010	0.007	4.512	4.8943
47	4.7000	4.0703	4.8000	0.022	0.011	4.8240	54.0	0.008	4.6015	4.6001	4.5984	4.5420	4.8000	4.6000	0.010	0.007	4.612	4.9915
48	4.8000	4.1569	4.9000	0.022	0.011	4.9240	54.0	0.008	4.7015	4.7001	4.6984	4.6447	4.9000	4.7000	0.010	0.007	4.712	5.0942
49	4.9000	4.2435	5.0000	0.022	0.011	5.0240	54.0	0.008	4.8015	4.8001	4.7983	4.7424	5.0000	4.8000	0.010	0.007	4.812	5.1917
50	5.0000	4.3301	5.1000	0.022	0.011	5.1240	54.0	0.008	4.9015	4.9001	4.8983	4.8449	5.1000	4.9000	0.010	0.007	4.912	5.2944

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] For dedendum, see Section 6. Dedendum of external spline is the same as the addendum.
[c] For space width and tooth thickness, see Tables 12a and 12b.
[d] L = 0.0001 × diameter (Col 39).
[e] J = 0.0002 × diameter (Col 39).
[f] If tighter fits are desired, use Col 29 or 30, Table 12b.

TABLE 24—*12/24 Diametral Pitch, Minor-Diameter Fits*[a]

12/24 Diametral Pitch Pressure Angle, 30°	Addendum[b] (Basic), 0.0417 Meas-Pin Diam (Int), 0.1200	Circular Pitch, 0.2618 Meas-Pin Diam (Ext), 0.1600

MINOR-DIAMETER FITS[c]

Internal and External			Internal										External					
N	Pitch diam, ref	Base-circle diam	*TIF* diam	Major-diam fillet		Major diam	Minor-diam chamfer		Minor diameter			Measurement between pins	Major diam	Minor diam, basic	Minor-diam fillet		*TIF* diam	Measurement over pins
				Rad	Ht		Ang	Ht	Cl X	Cl Y	Cl Z				Rad	Ht		
1	2	3	10	7	8	9-A	34	35	36	37	38	14	24	39	22	23	40	28
Recommended tolerance⟶			Min	App	Max	+0.0133 −0.0000	Deg	Min	+0.0019 + L^d −0.0000	+0.0006 + L^d −0.0000	+0.0000 −(0.0009 + L^d)	Max	+0.0000 −0.0050	+0.0000 −(0.0006 + J^e)	App	Max	Max	Min[f]
6	0.5000	0.4330	0.5833	0.012	0.004	0.6040	53.5	0.017	0.4182	0.4168	0.4159	0.3707	0.5833	0.4167	0.014	0.014	0.444	0.7342
7	0.5833	0.5052	0.6667	0.013	0.005	0.6873	53.5	0.015	0.5015	0.5001	0.4992	0.4399	0.6667	0.5000	0.013	0.013	0.525	0.8022
8	0.6667	0.5774	0.7500	0.014	0.006	0.7707	53.5	0.014	0.5848	0.5834	0.5825	0.5375	0.7500	0.5833	0.012	0.011	0.605	0.9031
9	0.7500	0.6495	0.8333	0.015	0.006	0.8540	53.5	0.013	0.6682	0.6668	0.6659	0.6097	0.8333	0.6667	0.011	0.011	0.688	0.9747
10	0.8333	0.7217	0.9167	0.015	0.006	0.9373	53.5	0.012	0.7515	0.7501	0.7491	0.7043	0.9167	0.7500	0.010	0.010	0.769	1.0711
11	0.9167	0.7939	1.0000	0.016	0.007	1.0207	53.5	0.011	0.8348	0.8334	0.8324	0.7767	1.0000	0.8333	0.010	0.009	0.851	1.1449
12	1.0000	0.8660	1.0833	0.016	0.007	1.1040	53.5	0.011	0.9182	0.9168	0.9158	0.8709	1.0833	0.9167	0.009	0.009	0.934	1.2389
13	1.0833	0.9382	1.1667	0.016	0.007	1.1873	53.5	0.010	1.0015	1.0001	0.9991	0.9465	1.1667	1.0000	0.009	0.009	1.017	1.3143
14	1.1667	1.0104	1.2500	0.017	0.007	1.2707	53.5	0.010	1.0848	1.0834	1.0824	1.0377	1.2500	1.0833	0.009	0.008	1.099	1.4065
15	1.2500	1.0825	1.3333	0.017	0.007	1.3540	53.5	0.010	1.1682	1.1668	1.1658	1.1142	1.3333	1.1667	0.009	0.008	1.182	1.4829
16	1.3333	1.1547	1.4167	0.017	0.008	1.4373	53.5	0.009	1.2515	1.2501	1.2490	1.2044	1.4167	1.2500	0.008	0.008	1.265	1.5738
17	1.4167	1.2269	1.5000	0.017	0.008	1.5207	53.5	0.009	1.3348	1.3334	1.3323	1.2816	1.5000	1.3333	0.008	0.008	1.348	1.6511
18	1.5000	1.2990	1.5833	0.017	0.008	1.6040	53.5	0.009	1.4182	1.4168	1.4157	1.3710	1.5833	1.4167	0.008	0.007	1.430	1.7411
19	1.5833	1.3712	1.6667	0.017	0.008	1.6873	53.5	0.009	1.5015	1.5001	1.4990	1.4489	1.6667	1.5000	0.008	0.007	1.513	1.8191
20	1.6667	1.4434	1.7500	0.017	0.008	1.7707	53.5	0.009	1.5848	1.5834	1.5823	1.5376	1.7500	1.5833	0.008	0.007	1.596	1.9082
21	1.7500	1.5155	1.8333	0.018	0.008	1.8540	53.5	0.008	1.6682	1.6668	1.6657	1.6164	1.8333	1.6667	0.008	0.007	1.680	1.9867
22	1.8333	1.5877	1.9167	0.018	0.008	1.9373	53.5	0.008	1.7515	1.7501	1.7489	1.7045	1.9167	1.7500	0.008	0.007	1.763	2.0754
23	1.9167	1.6599	2.0000	0.018	0.008	2.0207	53.5	0.008	1.8348	1.8334	1.8322	1.7834	2.0000	1.8333	0.008	0.007	1.846	2.1542
24	2.0000	1.7321	2.0833	0.018	0.008	2.1040	53.5	0.008	1.9182	1.9168	1.9156	1.8712	2.0833	1.9167	0.008	0.007	1.930	2.2423
25	2.0833	1.8042	2.1667	0.018	0.008	2.1873	53.5	0.008	2.0015	2.0001	1.9989	1.9504	2.1667	2.0000	0.008	0.007	2.013	2.3216
26	2.1667	1.8764	2.2500	0.018	0.008	2.2707	53.5	0.008	2.0848	2.0834	2.0822	2.0379	2.2500	2.0833	0.008	0.007	2.096	2.4093
27	2.2500	1.9486	2.3333	0.018	0.008	2.3540	53.5	0.008	2.1682	2.1668	2.1656	2.1174	2.3333	2.1667	0.008	0.006	2.178	2.4889
28	2.3333	2.0207	2.4167	0.018	0.008	2.4373	53.5	0.008	2.2515	2.2501	2.2488	2.2045	2.4167	2.2500	0.008	0.006	2.261	2.5761
29	2.4167	2.0929	2.5000	0.018	0.008	2.5207	53.5	0.008	2.3348	2.3334	2.3321	2.2838	2.5000	2.3333	0.008	0.006	2.344	2.6559
30	2.5000	2.1651	2.5833	0.018	0.009	2.6040	53.5	0.007	2.4182	2.4168	2.4155	2.3712	2.5833	2.4167	0.008	0.006	2.428	2.7431
31	2.5833	2.2372	2.6667	0.018	0.009	2.6873	53.5	0.007	2.5015	2.5001	2.4988	2.4512	2.6667	2.5000	0.008	0.006	2.511	2.8231
32	2.6667	2.3094	2.7500	0.018	0.009	2.7707	53.5	0.007	2.5848	2.5834	2.5821	2.5379	2.7500	2.5833	0.008	0.006	2.594	2.9099
33	2.7500	2.3816	2.8333	0.018	0.009	2.8540	53.5	0.007	2.6682	2.6668	2.6655	2.6182	2.8333	2.6667	0.008	0.006	2.678	2.9901
34	2.8333	2.4537	2.9167	0.018	0.009	2.9373	53.5	0.007	2.7515	2.7501	2.7487	2.7046	2.9167	2.7500	0.008	0.006	2.761	3.0767
35	2.9167	2.5259	3.0000	0.018	0.009	3.0207	53.5	0.007	2.8348	2.8334	2.8320	2.7851	3.0000	2.8333	0.008	0.006	2.844	3.1571
36	3.0000	2.5981	3.0833	0.018	0.009	3.1040	53.5	0.007	2.9182	2.9168	2.9154	2.8713	3.0833	2.9176	0.008	0.006	2.928	3.2436
37	3.0833	2.6702	3.1667	0.018	0.009	3.1873	53.5	0.007	3.0015	3.0001	2.9987	2.9519	3.1667	3.0000	0.008	0.006	3.011	3.3242
38	3.1667	2.7424	3.2500	0.018	0.009	3.2707	54.0	0.007	3.0848	3.0834	3.0820	3.0380	3.2500	3.0833	0.008	0.006	3.094	3.4104
39	3.2500	2.8146	3.3333	0.018	0.009	3.3540	54.0	0.007	3.1682	3.1668	3.1654	3.1187	3.3333	3.1667	0.008	0.006	3.178	3.4911
40	3.3333	2.8867	3.4167	0.018	0.009	3.4373	54.0	0.007	3.2515	3.2501	3.2486	3.2047	3.4167	3.2500	0.008	0.006	3.261	3.5772
41	3.4167	2.9589	3.5000	0.018	0.009	3.5207	54.0	0.007	3.3348	3.3334	3.3319	3.2855	3.5000	3.3333	0.008	0.006	3.344	3.6580
42	3.5000	3.0311	3.5833	0.019	0.009	3.6040	54.0	0.007	3.4182	3.4168	3.4153	3.3713	3.5833	3.4167	0.008	0.006	3.427	3.7440
43	3.5833	3.1033	3.6667	0.019	0.009	3.6873	54.0	0.007	3.5015	3.5001	3.4986	3.4523	3.6667	3.5000	0.008	0.006	3.511	3.8249
44	3.6667	3.1754	3.7500	0.019	0.009	3.7707	54.0	0.007	3.5848	3.5834	3.5819	3.5380	3.7500	3.5833	0.008	0.006	3.594	3.9108
45	3.7500	3.2476	3.8333	0.019	0.009	3.8540	54.0	0.007	3.6682	3.6668	3.6653	3.6190	3.8333	3.6667	0.008	0.006	3.677	3.9918
46	3.8333	3.3198	3.9167	0.019	0.009	3.9373	54.0	0.007	3.7515	3.7501	3.7485	3.7047	3.9167	3.7500	0.008	0.006	3.761	4.0776
47	3.9167	3.3919	4.0000	0.019	0.009	4.0207	54.0	0.007	3.8348	3.8334	3.8318	3.7858	4.0000	3.8333	0.008	0.006	3.844	4.1585
48	4.0000	3.4641	4.0833	0.019	0.009	4.1040	54.0	0.007	3.9182	3.9168	3.9152	3.8714	4.0833	3.9176	0.008	0.006	3.927	4.2441
49	4.0833	3.5363	4.1667	0.019	0.009	4.1873	54.0	0.007	4.0015	4.0001	3.9985	3.9528	4.1667	4.0000	0.008	0.006	4.011	4.3254
50	4.1667	3.6084	4.2500	0.019	0.009	4.2707	54.0	0.007	4.0848	4.0834	4.0818	4.0382	4.2500	4.0833	0.008	0.005	4.092	4.4109

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] For dedendum, see Section 6. Dedendum of external spline is the same as the addendum.
[c] For space width and tooth thickness, see Tables 13a and 13b.
[d] L = 0.0001 × diameter (Col 39).
[e] J = 0.0002 × diameter (Col 39).
[f] If tighter fits are desired, use Col 29 or 30, Table 13b.

TABLE 25—*16/32 Diametral Pitch, Minor-Diameter Fits*[a]

16/32 Diametral Pitch
Pressure Angle, 30°

Addendum[b] (Basic), 0.0313
Meas-Pin Diam (Int), 0.0900

Circular Pitch, 0.1963
Meas-Pin Diam (Ext), 0.1200

MINOR-DIAMETER FITS[c]

Internal and External			Internal										External					
N	Pitch diam, ref	Base-circle diam	*TIF* diam	Major-diam fillet		Major diam	Minor-diam chamfer		Minor diameter			Measurement between pins	Major diam	Minor diam, basic	Minor-diam fillet		*TIF* diam	Measurement over pins
				Rad	Ht		Ang	Ht	Cl X	Cl Y	Cl Z				Rad	Ht		
1	2	3	10	7	8	9-A	34	35	36	37	38	14	24	39	22	23	40	28
Recommended tolerance⟶			Min	App	Max	+0.0112 −0.0000	Deg	Min	+0.0019 + L^d −0.0000	+0.0006 + L^d −0.0000	+0.0000 −(0.0009 + L^d)	Max	+0.0000 −0.0050	+0.0000 −(0.0006 + J^e)	App	Max	Max	Min[f]
6	0.3750	0.3248	0.4375	0.009	0.003	0.4540	53.5	0.013	0.3140	0.3126	0.3117	0.2792	0.4375	0.3125	0.011	0.011	0.334	0.5495
7	0.4375	0.3789	0.5000	0.010	0.004	0.5165	53.5	0.011	0.3765	0.3751	0.3742	0.3310	0.5000	0.3750	0.009	0.009	0.392	0.6005
8	0.5000	0.4330	0.5625	0.011	0.004	0.5790	53.5	0.010	0.4390	0.4376	0.4367	0.4043	0.5625	0.4375	0.009	0.009	0.455	0.6761
9	0.5625	0.4871	0.6250	0.011	0.004	0.6415	53.5	0.010	0.5015	0.5001	0.4992	0.4584	0.6250	0.5000	0.008	0.008	0.515	0.7298
10	0.6250	0.5413	0.6875	0.012	0.005	0.7040	53.5	0.009	0.5640	0.5626	0.5617	0.5294	0.6875	0.5625	0.008	0.007	0.576	0.8021
11	0.6875	0.5954	0.7500	0.012	0.005	0.7665	53.5	0.008	0.6265	0.6251	0.6242	0.5849	0.7500	0.6250	0.007	0.007	0.638	0.8574
12	0.7500	0.6495	0.8125	0.012	0.005	0.8290	53.5	0.008	0.6890	0.6876	0.6867	0.6543	0.8125	0.6875	0.007	0.007	0.701	0.9279
13	0.8125	0.7036	0.8750	0.012	0.005	0.8915	53.5	0.008	0.7515	0.7501	0.7491	0.7110	0.8750	0.7500	0.007	0.006	0.761	0.9844
14	0.8750	0.7578	0.9375	0.012	0.005	0.9540	53.5	0.007	0.8140	0.8126	0.8116	0.7794	0.9375	0.8125	0.007	0.006	0.824	1.0535
15	0.9375	0.8119	1.0000	0.013	0.006	1.0165	53.5	0.007	0.8765	0.8751	0.8741	0.8368	1.0000	0.8750	0.006	0.006	0.886	1.1109
16	1.0000	0.8660	1.0625	0.013	0.006	1.0790	53.5	0.007	0.9390	0.9376	0.9366	0.9045	1.0625	0.9375	0.006	0.006	0.949	1.1790
17	1.0625	0.9202	1.1250	0.013	0.006	1.1415	53.5	0.007	1.0015	1.0001	0.9991	0.9623	1.1250	1.0000	0.006	0.006	1.011	1.2370
18	1.1250	0.9743	1.1875	0.013	0.006	1.2040	53.5	0.007	1.0640	1.0626	1.0616	1.0294	1.1875	1.0625	0.006	0.006	1.074	1.3045
19	1.1875	1.0284	1.2500	0.013	0.006	1.2665	53.5	0.007	1.1265	1.1251	1.1241	1.0878	1.2500	1.1250	0.006	0.005	1.134	1.3629
20	1.2500	1.0825	1.3125	0.013	0.006	1.3290	53.5	0.006	1.1890	1.1876	1.1866	1.1543	1.3125	1.1875	0.006	0.005	1.197	1.4298
21	1.3125	1.1367	1.3750	0.013	0.006	1.3915	53.5	0.006	1.2515	1.2501	1.2490	1.2134	1.3750	1.2500	0.006	0.005	1.259	1.4886
22	1.3750	1.1908	1.4375	0.013	0.006	1.4540	53.5	0.006	1.3140	1.3126	1.3115	1.2795	1.4375	1.3125	0.006	0.005	1.322	1.5552
23	1.4375	1.2449	1.5000	0.013	0.006	1.5165	53.5	0.006	1.3765	1.3751	1.3740	1.3387	1.5000	1.3750	0.006	0.005	1.384	1.6143
24	1.5000	1.2990	1.5625	0.013	0.006	1.5790	53.5	0.006	1.4390	1.4376	1.4365	1.4045	1.5625	1.4375	0.006	0.005	1.447	1.6804
25	1.5625	1.3532	1.6250	0.013	0.006	1.6415	53.5	0.006	1.5015	1.5001	1.4990	1.4640	1.6250	1.5000	0.006	0.005	1.509	1.7398
26	1.6250	1.4073	1.6875	0.013	0.006	1.7040	53.5	0.006	1.5640	1.5626	1.5615	1.5296	1.6875	1.5625	0.006	0.005	1.572	1.8056
27	1.6875	1.4614	1.7500	0.013	0.006	1.7665	53.5	0.006	1.6265	1.6251	1.6240	1.5892	1.7500	1.6250	0.006	0.005	1.634	1.8653
28	1.7500	1.5155	1.8125	0.014	0.006	1.8290	53.5	0.006	1.6890	1.6876	1.6865	1.6546	1.8125	1.6875	0.006	0.005	1.697	1.9306
29	1.8125	1.5697	1.8750	0.014	0.006	1.8915	53.5	0.006	1.7515	1.7501	1.7489	1.7144	1.8750	1.7500	0.006	0.005	1.759	1.9905
30	1.8750	1.6238	1.9375	0.014	0.006	1.9540	53.5	0.006	1.8140	1.8126	1.8114	1.7796	1.9375	1.8125	0.006	0.005	1.822	2.0558
31	1.9375	1.6779	2.0000	0.014	0.006	2.0165	53.5	0.006	1.8765	1.8751	1.8739	1.8396	2.0000	1.8750	0.006	0.005	1.884	2.1159
32	2.0000	1.7321	2.0625	0.014	0.006	2.0790	53.5	0.006	1.9390	1.9376	1.9364	1.9046	2.0625	1.9375	0.006	0.005	1.947	2.1809
33	2.0625	1.7862	2.1250	0.014	0.006	2.1415	53.5	0.005	2.0015	2.0001	1.9989	1.9648	2.1250	2.0000	0.006	0.005	2.009	2.2411
34	2.1250	1.8403	2.1875	0.014	0.006	2.2040	53.5	0.005	2.0640	2.0626	2.0614	2.0296	2.1875	2.0625	0.006	0.005	2.072	2.3061
35	2.1875	1.8944	2.2500	0.014	0.007	2.2665	53.5	0.005	2.1265	2.1251	2.1239	2.0900	2.2500	2.1250	0.006	0.004	2.132	2.3664
36	2.2500	1.9486	2.3125	0.014	0.007	2.3290	53.5	0.005	2.1890	2.1876	2.1864	2.1547	2.3125	2.1875	0.006	0.004	2.195	2.4312
37	2.3125	2.0027	2.3750	0.014	0.007	2.3915	53.5	0.005	2.2515	2.2501	2.2488	2.2151	2.3750	2.2500	0.006	0.004	2.257	2.4916
38	2.3750	2.0568	2.4375	0.014	0.007	2.4540	54.0	0.005	2.3140	2.3126	2.3113	2.2797	2.4375	2.3125	0.006	0.004	2.319	2.5564
39	2.4375	2.1109	2.5000	0.014	0.007	2.5165	54.0	0.005	2.3765	2.3751	2.3738	2.3402	2.5000	2.3750	0.006	0.004	2.382	2.6169
40	2.5000	2.1651	2.5625	0.014	0.007	2.5790	54.0	0.005	2.4390	2.4376	2.4363	2.4047	2.5625	2.4375	0.006	0.004	2.444	2.6814
41	2.5625	2.2192	2.6250	0.014	0.007	2.6415	54.0	0.005	2.5015	2.5001	2.4988	2.4653	2.6250	2.5000	0.006	0.004	2.507	2.7420
42	2.6250	2.2733	2.6875	0.014	0.007	2.7040	54.0	0.005	2.5640	2.5626	2.5613	2.5297	2.6875	2.5625	0.006	0.004	2.569	2.8065
43	2.6875	2.3274	2.7500	0.014	0.007	2.7665	54.0	0.005	2.6265	2.6251	2.6238	2.5904	2.7500	2.6250	0.006	0.004	2.632	2.8672
44	2.7500	2.3816	2.8125	0.014	0.007	2.8290	54.0	0.005	2.6890	2.6876	2.6863	2.6547	2.8125	2.6875	0.006	0.004	2.694	2.9316
45	2.8125	2.4357	2.8750	0.014	0.007	2.8915	54.0	0.005	2.7515	2.7501	2.7487	2.7154	2.8750	2.7500	0.006	0.004	2.757	2.9924
46	2.8750	2.4898	2.9375	0.014	0.007	2.9540	54.0	0.005	2.8140	2.8126	2.8112	2.7797	2.9375	2.8125	0.006	0.004	2.819	3.0567
47	2.9375	2.5440	3.0000	0.014	0.007	3.0165	54.0	0.005	2.8765	2.8751	2.8737	2.8385	3.0000	2.8750	0.006	0.004	2.882	3.1173
48	3.0000	2.5981	3.0625	0.014	0.007	3.0790	54.0	0.005	2.9390	2.9376	2.9362	2.9047	3.0625	2.9375	0.006	0.004	2.944	3.1816
49	3.0625	2.6522	3.1250	0.014	0.007	3.1415	54.0	0.005	3.0015	3.0001	2.9987	2.9658	3.1250	3.0000	0.006	0.004	3.007	3.2425
50	3.1250	2.7063	3.1875	0.014	0.007	3.2040	54.0	0.005	3.0640	3.0626	3.0612	3.0299	3.1875	3.0625	0.006	0.004	3.069	3.3066

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] For dedendum, see Section 6. Dedendum of external spline is the same as the addendum.
[c] For space width and tooth thickness, see Tables 14a and 14b.
[d] L = 0.0001 × diameter (Col 39).
[e] J = 0.0002 × diameter (Col 39).
[f] If tighter fits are desired, use Col 29 or 30, Table 14b.

TABLE 26—*Machining Tolerances and Formulas for Dimensions in Tables 5 Through 25*

COLUMN NUMBER	CLASS OF FIT	DIAMETRAL PITCH	FORMULA FOR COLUMN DIMENSION	MACHINING TOLERANCE
2	—	All pitches	$D = N/P$	—
3	—	All pitches	$D_b = D \cos 30°$	—
4	—	All pitches	$D_o = \dfrac{N+1}{P}$	$+(0.0007 + 0.0001\ D_o)$ -0.0000
5	—	All pitches	Col 4 − 2 (Col 8)	Minimum
6, 11, 27	—	1/2 thru 4/8 5/10 thru 8/16 10/20 thru 20/40 24/48 thru 48/96	$D_R = \dfrac{N-1}{P}$ (For 1/2 thru 20/40, 6 and 7 teeth, $D_R = D_b + 0.010$) (For 24/48 thru 48/96, 6 and 7 teeth, $D_R = D_b + 0.25(D - D_b)$ (Arbitrary correction on 8 tooth for 2.5/5 thru 12/24)	+ 0.0050 − 0.0000 + 0.0035 − 0.0000 + 0.0025 − 0.0000 + 0.0015 − 0.0000
7, 8, 19, 20 22, 23, 26, 35	—	All pitches	Determined by layout for 1/2 diametral pitch. Divide dimension for 1/2 diametral pitch by that used.	—
9A	—	All pitches	$D_o = \dfrac{N+1.2}{P} + 0.0040$ (clearance, $c = \dfrac{0.1}{P} + 0.002$)	$+\left(\dfrac{0.1}{P} + 0.005\right)$ $-\ 0$
9B	—	All pitches	$D_o = \dfrac{N+1}{P}$	$+\ (0.0007 + 0.0001\ D_o)$ $-\ (0.0007 + 0.0001\ D_o)$
10	—	All pitches	$TIF = \dfrac{N+1}{P}$	Minimum
12	—	All pitches	$D_o = \dfrac{N+1.8}{P}$	$+\left(\dfrac{0.1}{P} + 0.005\right)$ $-\ 0$
14	—	1/2 2.5/5 3/6 4/8 and 5/10 6/12 and 8/16 10/20 thru 48/96	Obtain M_i from Table 28 or calculate from formula (5) or (6), Fig. 3B. Measurement = Basic $M_i + 0.0001\ F\ (0.396\ N + 45)$ Basic $M_i + 0.0001\ F\ (0.156\ N + 42)$ Basic $M_i + 0.0001\ F\ (0.132\ N + 40)$ Basic $M_i + 0.0001\ F\ (0.096\ N + 37)$ Basic $M_i + 0.0001\ F\ (0.072\ N + 30)$ Basic $M_i + 0.0001\ F\ (0.072\ N + 24)$	Maximum tolerance is included in formulas, see Section 25. For lead allowances see Table 27.
15	—	1/2 2.5/5 3/6 4/8 and 5/10 6/12 and 8/16 10/20 thru 48/96	Minimum is basic, see Section 6. Maximum is basic plus (this includes machining tolerance) $0.0001\ (0.396\ N + 45)$ $0.0001\ (0.156\ N + 42)$ $0.0001\ (0.132\ N + 40)$ $0.0001\ (0.096\ N + 37)$ $0.0001\ (0.072\ N + 30)$ $0.0001\ (0.072\ N + 24)$	+ 0.0020 − 0.0000 For reference only, + 0.0020 − 0.0000 included in maximum[a] + 0.0020 − 0.0000 + 0.0020 − 0.0000 + 0.0015 − 0.0000 + 0.0010 − 0.0000
16	I	All pitches	$D_o - 0.0015$, or Col 4 − 0.0015	$+\ 0.0000 - (0.0019 + 0.0002 D_o)$
17	II	All pitches	$D_o - 0.0001$, or Col 4 − 0.0001	$+\ 0.0000 - (0.0006 + 0.0002 D_o)$
18	III	All pitches	$D_o + 0.0008 + 0.0001 D_o$	$+\ (0.0009 + 0.0002 D_o) - 0.0000$
21	—	All pitches	$D_R = \dfrac{N-1.2}{P} - 0.0040$	$+\ 0$ $-\left(\dfrac{0.1}{P} + 0.005\right)$
24	—	1/2 thru 4/8 5/10 thru 8/16 10/20 thru 20/40 24/48 thru 48/96	$D_o = \dfrac{N+1}{P}$	+0.0000 − 0.0100 +0.0000 − 0.0070 +0.0000 − 0.0050 +0.0000 − 0.0030
25	—	1/2 thru 12/24 16/32 thru 48/96	$D_R = \dfrac{N-1.8}{P}$ $D_R = \dfrac{N-2.0}{P}$	$+\ 0$ $-\left(\dfrac{0.1}{P} + 0.005\right)$
28	A	1/2 2.5/5 3/6 4/8 and 5/10 6/12 and 8/16 10/20 thru 20/40 24/48 thru 48/96	Obtain M_e from Table 29 or calculate from formula (2) or (3), Fig. 3A. Measurement = Basic $M_e - 0.0001\ E\ (0.360\ N + 52)$ Basic $M_e - 0.0001\ E\ (0.120\ N + 45)$ Basic $M_e - 0.0001\ E\ (0.090\ N + 47)$ Basic $M_e - 0.0001\ E\ (0.072\ N + 43)$ Basic $M_e - 0.0001\ E\ (0.054\ N + 36)$ Basic $M_e - 0.0001\ E\ (0.054\ N + 35)$ Basic $M_e - 0.0001\ E\ (0.054\ N + 30)$	+0.0000 − 0.0020 For reference only, included in minimum[a] +0.0000 − 0.0020 +0.0000 − 0.0020 +0.0000 − 0.0020 +0.0000 − 0.0015 +0.0000 − 0.0010 +0.0000 − 0.0010
29	B	1/2 2.5/5 3/6 4/8 and 5/10 6/12 and 8/16 10/20 thru 20/40 24/48 thru 48/96	Obtain M_e from Table 29 or calculate from formula (2) or (3), Fig. 3A. Measurement = Basic $M_e - 0.0001\ E\ (0.360\ N + 27)$ Basic $M_e - 0.0001\ E\ (0.120\ N + 23)$ Basic $M_e - 0.0001\ E\ (0.090\ N + 22)$ Basic $M_e - 0.0001\ E\ (0.072\ N + 18)$ Basic $M_e - 0.0001\ E\ (0.054\ N + 18)$ Basic $M_e - 0.0001\ E\ (0.054\ N + 19)$ Basic $M_e - 0.0001\ E\ (0.054\ N + 16)$	+0.0000 − 0.0015 For reference only, included in minimum[a] +0.0000 − 0.0015 +0.0000 − 0.0015 +0.0000 − 0.0015 +0.0000 − 0.0015 +0.0000 − 0.0015 +0.0000 − 0.0010

(*Continued on next page.*)

TABLE 26—*Machining Tolerances and Formulas for Dimensions in Tables 5 Through 25 (Concluded)*

COLUMN NUMBER	CLASS OF FIT	DIAMETRAL PITCH	FORMULA FOR COLUMN DIMENSION	MACHINING TOLERANCE
30	C	1/2	Obtain M_e from Table 29 or calculate from formula (2) or (3), Fig. 3A. Measurement = Basic $M_e - 0.0001\,E\,(0.360\,N - 3)$	$+0.0000 - 0.0015$
		2.5/5	Basic $M_e - 0.0001\,E\,(0.120\,N - 4)$	For reference only, included in minimum[a] $+0.0000 - 0.0015$
		3/6	Basic $M_e - 0.0001\,E\,(0.090\,N - 5)$	$+0.0000 - 0.0015$
		4/8 and 5/10	Basic $M_e - 0.0001\,E\,(0.072\,N - 3)$	$+0.0000 - 0.0015$
		6/12 and 8/16	Basic $M_e - 0.0001\,E\,(0.054\,N + 1)$	$+0.0000 - 0.0015$
		10/20 thru 20/40	Basic $M_e - 0.0001\,E\,(0.054\,N)$	$+0.0000 - 0.0015$
		24/48 thru 48/96	Basic $M_e - 0.0001\,E\,(0.054\,N - 5)$	$+0.0000 - 0.0010$
31	A	1/2	Max: Basic $- 0.0005$; Min: Basic $- 0.0001\,(0.360\,N + 52)$	$+0.0000 - 0.0020$
		2.5/5	Basic $- 0.0005$; Basic $- 0.0001\,(0.120\,N + 48)$	For reference only, included in minimum[a] $+0.0000 - 0.0020$
		3/6	Basic $- 0.0005$; Basic $- 0.0001\,(0.090\,N + 47)$	
		4/8 to 5/10	Basic $- 0.0005$; Basic $- 0.0001\,(0.072\,N + 43)$	$+0.0000 - 0.0020$
		6/12 to 8/16	Basic $- 0.0005$; Basic $- 0.0001\,(0.054\,N + 36)$	$+0.0000 - 0.0015$
		10/20 to 20/40	Basic $- 0.0005$; Basic $- 0.0001\,(0.054\,N + 35)$	$+0.0000 - 0.0015$
		24/48 to 48/96	Basic $- 0.0005$; Basic $- 0.0001\,(0.054\,N + 30)$	$+0.0000 - 0.0010$
32	B	1/2	Max: Basic $+ 0.0015$; Min: Basic $- 0.0001\,(0.360\,N + 27)$	$+0.0000 - 0.0015$
		2.5/5	Basic $+ 0.0015$; Basic $- 0.0001\,(0.120\,N + 23)$	$+0.0000 - 0.0015$
		3/6	Basic $+ 0.0015$; Basic $- 0.0001\,(0.090\,N + 22)$	For reference only, included in minimum[a] $+0.0000 - 0.0015$
		4/8 to 5/10	Basic $+ 0.0015$; Basic $- 0.0001\,(0.072\,N + 18)$	$+0.0000 - 0.0015$
		6/12 to 8/16	Basic $+ 0.0013$; Basic $- 0.0001\,(0.054\,N + 18)$	$+0.0000 - 0.0015$
		10/20 to 20/40	Basic $+ 0.0011$; Basic $- 0.0001\,(0.054\,N + 19)$	$+0.0000 - 0.0015$
		24/48 to 48/96	Basic $+ 0.0009$; Basic $- 0.0001\,(0.054\,N + 16)$	$+0.0000 - 0.0010$
33	C	1/2	Max: Basic $+ 0.0045$; Min: Basic $- 0.0001\,(0.360\,N - 3)$	$+0.0000 - 0.0015$
		2.5/5	Basic $+ 0.0042$; Basic $- 0.0001\,(0.120\,N - 4)$	$+0.0000 - 0.0015$
		3/6	Basic $+ 0.0042$; Basic $- 0.0001\,(0.090\,N - 5)$	For reference only, included in minimum[a] $+0.0000 - 0.0015$
		4/8 to 5/10	Basic $+ 0.0036$; Basic $- 0.0001\,(0.072\,N - 3)$	$+0.0000 - 0.0015$
		6/12 to 8/16	Basic $+ 0.0030$; Basic $- 0.0001\,(0.054\,N + 1)$	$+0.0000 - 0.0015$
		10/20 to 20/40	Basic $+ 0.0030$; Basic $- 0.0001\,(0.054\,N)$	$+0.0000 - 0.0015$
		24/48 to 48/96	Basic $+ 0.0030$; Basic $- 0.0001\,(0.054\,N - 5)$	$+0.0000 - 0.0010$
34	X, Y, Z	All pitches	Determined by layout.	—
36	X	All pitches	$D_R = \frac{N-1}{P} + 0.0015$	$+ (0.0019 + 0.0001\,D_R)$ $- 0.0000$
37	Y	All pitches	$D_R = \frac{N-1}{P} + 0.0001$	$+ (0.0006 + 0.0001\,D_R)$ -0.0000
38	Z	All pitches	$D_R = \frac{N-1}{P} - (0.0007 + 0.0002\,D_R)$	$+ 0.0000$ $- (0.0009 + 0.0001\,D_R)$
39	X, Y, Z	All pitches	$D_R = \frac{N-1}{P}$ Same as Col 6, except for $N = 6$ and 7	$+0.0000$ $-(0.0006 + 0.0002\,D_R)$
40	X, Y, Z	All pitches	$TIF = \frac{N-1}{P} + 2$ (Col 23)	—

[a] These tolerances are included in the formulas given and are shown for reference only.

25. Pin Measurements

Internal Splines—Minimum pin measurements are not specified because they should not be the basis for rejection as long as effective size, controlled by gages, is not below the specified minimum. When it is not feasible to check effective sizes, a minimum pin measurement may be used which is equal to the maximum pin measurement minus the machining tolerance (Table 26) times factor F. This minimum pin measurement may, however, be reduced as allowable errors are reduced.

For fillet-root type splines, the table dimensions may be used for pins as specified, without flattening. For the flat-root type, which must be used with classes I, II, III, X, Y, and Z fits, round measuring pins may be used, but these will vary in diameter with number of teeth. Any pin which will contact the involute form and not touch the major diameter may be used. The largest pin which can be used will contact the tooth at its tip, as shown in Fig. 6A; and the smallest pin which may be used will touch the major diameter at the same time it contacts the involute tooth, as shown in Fig. 6B.

A pin contacting at the pitch point may not be the smallest usable size, but it does form a good starting point for determining the smallest practical diameter. When a pin contacts at the pitch point,

$$\phi_i = 30° - \frac{90°}{N}$$

If ϕ_i is less than $30° - \frac{90°}{N}$, the contact is inside the pitch

circle; and if greater, it is outside. The smallest angle results from using the largest pin and is shown in Fig. 6A, in which

$$\cos \phi_x = \frac{D_b}{D_R} = \frac{\text{Col 3}}{\text{Col 6}}$$

For any diameter, the minimum angle for ϕ_i may be found by using the formula

$$\tan \phi_i = \tan \phi_x - \frac{d_i}{D_b}$$

From these conditions, Table 32 has been developed. Col 4 represents the smallest available pin. Clearance, Col 6, is for 1/2-diametral pitch and will be proportionally smaller for other diametral pitches. If the clearance is smaller than the machining tolerance (Table 26) times the factor F, a splined part with a tooth space width near the high limit would allow the pin to contact the major diameter and give a false dimension. To provide for such conditions, oversize pins are listed with the clearance and pin measurement.

External Splines—Maximum pin measurements are not specified because they should not be the basis for rejection as long as effective size, controlled by gages, is not above the specified maximum. When it is not feasible to check effective sizes, a maximum pin measurement may be used which is equal to the minimum pin measurement plus the machining tolerance (Table 26) times factor E. This maximum pin measurement may, however, be increased as allowable errors are reduced.

26. **Three-Pin System**—If three pins are used for measurement, as shown in Fig. 7, a shaft must be used whose diameter will be D_b sec ϕ_i–d_i for both even and odd numbers of teeth. For even numbers of teeth, the table dimensions may be used, but for odd numbers of teeth the measurements must be calculated by formulas (4) and (5), Fig. 3B.

27. **Production Practice**—Instead of pins, gages are usually used for quantity production, because such gages are made to inspect size, spacing errors (pitch), and parallelism (lead). All dimensions in the Standard, however, are calculated from the basic dimensions over pins. The usual way to check plug- and ring-gage measurements is by the use of pins.

28. **Effective Fits**—The definition in Section 20, and Table 2, show the end result after all allowable errors have been accumulated. The effective space width of the internal spline is equal to the dimensional space width minus a portion of the total of all allowable errors, and likewise the effective tooth thickness of the external spline is equal to the dimensional thickness plus a portion of the total of all allowable errors. Tolerances in the tables are for a complete gaging system. For pin measurement and instrument checking, calculate as directed in Section 25.

29. **Allowable Errors**

(a)—*Accumulated Pitch Error* (*Spacing*) is the greatest difference in any two teeth between the actual and theoretical tooth spacing on the same circle. Measurements are taken from one pitch point selected as reference to the corresponding points on all other teeth, and they will be affected by involute error and out of roundness.

(b)—*Profile Error* is the difference between the highest and lowest readings of a dial indicator moving along the true involute curve in the plane of rotation and having a finger contacting the active tooth profile.

(c)—*Lead Error* is a deviation of the teeth from the dimensional lead of the spline. Lead error is usually measured by traversing a dial indicator along the tooth face normal to the pitch line and parallel to the axis of the spline. This error may be disregarded unless experience shows otherwise.

(d)—*Out of Roundness* is the difference between the maximum and minimum measurements over or between pins.

(e)—*Application of Errors*. Experience has shown that not all of the possible extremes will occur at one time, so that instead of using the total of all errors, 60% has been adopted as a fair maximum for computing effective fits. (See Section 21.)

Allowable errors are shown in Table 27. All figures given in this table are in ten thousandths of an inch.

The allowable errors in Table 27 are based on Class 3 of Gear Tolerances and Inspection, ASA B6.6-1946. That standard is based on experience with gear-generating machines. When the internal spline is broached, smaller allowances may be used for mass production with the consent of the broach maker. If less accuracy can be permitted, 133% of the errors in the table may be used. In all cases, 60% of the total for calculating effective fits should be used.

To obtain total allowable errors, add the out of roundness divided by F or E to the profile error and the accumulated pitch

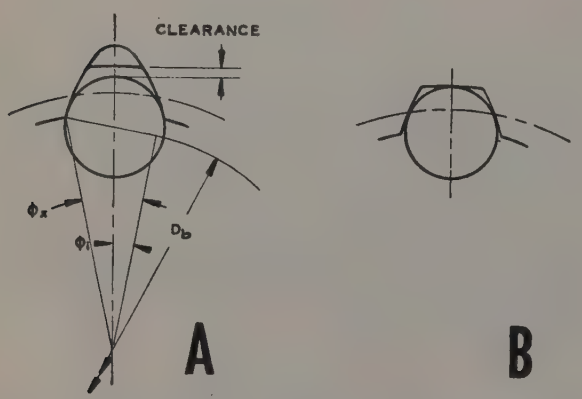


Fig. 6—Largest (A) and Smallest (B) Pin for Measurement of Internal Splines

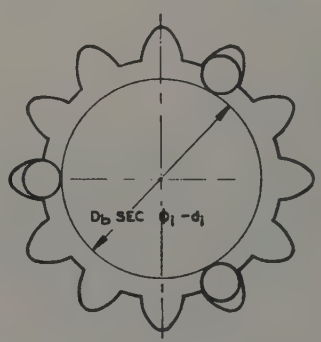


Fig. 7—Three-Pin System of Measurement

TABLE 27—*Allowable Errors*[a]

DIAMETRAL PITCH	INVOLUTE PROFILE ERRORS	ACCUMULATED PITCH ERROR BETWEEN ANY TWO TEETH — Use as given or interpolate as required — Number of teeth													LEAD ERRORS — Length of spline					
		6	8	10	12	14	16	20	25	30	35	40	45	50	0 to 0.49	0.50 to 1.24	1.25 to 2.49	2.50 to 3.99	4.00 to 5.24	5.25 to 6.50
1/2	15	22	22	22	22	23	24	27	30	33	36	39	42	45	0	4	5	6	7	8
2.5/5	11	20	20	20	20	20	20	20	20	20	21	22	23	24	0	4	5	6	7	8
3/6	10	18	18	18	18	18	18	18	18	18	18	19	20	20	0	4	5	6	7	8
4/8 and 5/10	8	15	15	15	15	15	15	15	15	15	15	15	15	15	0	4	5	6	7	8
6/12 and 8/16	6	15	15	15	15	15	15	15	15	15	15	15	15	15	0	3	3	4	5	6
10/20 up	5	15	15	15	15	15	15	15	15	15	15	15	15	15	0	3	3	4	5	6

DIAMETRAL PITCH	OUT OF ROUNDNESS — Internal spline, number of teeth													External spline, number of teeth										
	6	8	10	12	14	16	20	25	30	35	40	45	50	6	8	10	12	14	16	20	25	30	35	40	45	50
1/2	17	19	21	24	23	23	24	24	24	25	25	26	26	16	18	20	23	23	24	24	24	25	25	25	25	25
2.5/5	13	13	14	15	16	17	18	20	23	23	23	23	24	12	13	14	15	16	17	18	20	22	22	22	22	22
3/6	12	13	13	14	14	15	17	19	20	22	23	24	24	12	12	14	14	15	15	17	18	20	21	21	21	21
4/8 and 5/10	11	12	12	13	13	13	15	16	17	18	20	21	22	10	11	11	12	13	13	14	15	16	18	19	20	21
6/12 thru 48/96	9	9	10	10	10	11	11	12	13	14	15	16	17	8	9	10	10	10	11	12	12	14	14	15	16	17

[a] All table figures are ten thousandths of an inch.

error; multiply this total by 60%. The result is the total of all allowable errors to be used.

The formulas in Table 26 are based on 60% of the total allowable errors except lead. The machining tolerances are also included in these formulas. If allowance for lead must be included, add 60% of the error to the space width, (Col 15, max) for the internal, or deduct from the tooth thickness (Col 31, 32, or 33, min) for the external spline.

Pin measurements (Col 14, Tables 5 through 19) must be increased (when allowance for lead error is added) by adding the lead error multiplied by 60% and by F (Table 4). Likewise, pin measurements (Col 28, 29, or 30) must be decreased by the amount of the allowance for lead error multiplied by 60% and by E.

(*Text continued after table 39.*)

TABLE 28—*Basic Measurements Between Pins*[a]

N	DIAMETRAL PITCH														
	1/2	2.5/5	3/6	4/8	5/10	6/12	8/16	10/20	12/24	16/32	20/40	24/48	32/64	40/80	48/96
6	4.3933	1.7573	1.4644	1.0983	0.8787	0.7322	0.5492	0.4393	0.3661	0.2746	0.2197	0.1831	0.1373	0.1098	0.0915
7	5.2232	2.0892	1.7410	1.3058	1.0446	0.8705	0.6529	0.5223	0.4353	0.3264	0.2612	0.2176	0.1632	0.1306	0.1088
8	6.3954	2.5582	2.1318	1.5989	1.2791	1.0659	0.7994	0.6395	0.5329	0.3997	0.3198	0.2665	0.1999	0.1599	0.1332
9	7.2618	2.9047	2.4206	1.8155	1.4524	1.2103	0.9077	0.7262	0.6052	0.4539	0.3631	0.3026	0.2269	0.1815	0.1513
10	8.3966	3.3586	2.7989	2.0992	1.6793	1.3994	1.0496	0.8397	0.6997	0.5248	0.4198	0.3499	0.2624	0.2099	0.1749
11	9.2867	3.7147	3.0956	2.3217	1.8573	1.5478	1.1608	0.9287	0.7739	0.5804	0.4643	0.3869	0.2902	0.2322	0.1935
12	10.3973	4.1589	3.4658	2.5993	2.0795	1.7329	1.2997	1.0397	0.8664	0.6498	0.5199	0.4332	0.3249	0.2599	0.2166
13	11.3040	4.5216	3.7680	2.8260	2.2608	1.8840	1.4130	1.1304	0.9420	0.7065	0.5652	0.4710	0.3533	0.2826	0.2355
14	12.3978	4.9591	4.1326	3.0995	2.4796	2.0663	1.5497	1.2398	1.0332	0.7749	0.6199	0.5166	0.3874	0.3099	0.2583
15	13.3167	5.3267	4.4389	3.3292	2.6633	2.2195	1.6646	1.3317	1.1097	0.8323	0.6658	0.5549	0.4161	0.3329	0.2774
16	14.3982	5.7593	4.7994	3.5996	2.8796	2.3997	1.7998	1.4398	1.1999	0.8999	0.7199	0.5999	0.4499	0.3600	0.3000
17	15.3265	6.1306	5.1089	3.8317	3.0653	2.5544	1.9158	1.5327	1.2772	0.9579	0.7663	0.6386	0.4790	0.3832	0.3193
18	16.3985	6.5594	5.4662	4.0996	3.2797	2.7331	2.0498	1.6399	1.3665	1.0249	0.8199	0.6833	0.5125	0.4100	0.3416
19	17.3343	6.9337	5.7781	4.3336	3.4669	2.8891	2.1668	1.7335	1.4445	1.0834	0.8667	0.7223	0.5417	0.4334	0.3611
20	18.3987	7.3595	6.1329	4.5997	3.6797	3.0665	2.2998	1.8399	1.5332	1.1499	0.9199	0.7666	0.5750	0.4600	0.3833
21	19.3405	7.7362	6.4468	4.8351	3.8681	3.2234	2.4176	1.9341	1.6118	1.2088	0.9670	0.8059	0.6044	0.4835	0.4029
22	20.3989	8.1596	6.7996	5.0997	4.0798	3.3998	2.5499	2.0399	1.6999	1.2749	1.0199	0.8500	0.6375	0.5100	0.4250
23	21.3457	8.5383	7.1152	5.3364	4.2691	3.5576	2.6682	2.1346	1.7788	1.3341	1.0673	0.8894	0.6671	0.5337	0.4447
24	22.3991	8.9596	7.4664	5.5998	4.4798	3.7332	2.7999	2.2399	1.8666	1.3999	1.1199	0.9333	0.7000	0.5600	0.4666
25	23.3501	9.3400	7.7834	5.8375	4.6700	3.8917	2.9188	2.3350	1.9459	1.4595	1.1676	0.9730	0.7297	0.5838	0.4865
26	24.3992	9.7597	8.1331	6.0998	4.8798	4.0665	3.0499	2.4399	2.0333	1.5250	1.2200	1.0166	0.7625	0.6100	0.5083
27	25.3538	10.1415	8.4513	6.3385	5.0708	4.2256	3.1692	2.5354	2.1128	1.5846	1.2677	1.0564	0.7923	0.6339	0.5282
28	26.3993	10.5597	8.7998	6.5998	5.2799	4.3999	3.2999	2.6399	2.1999	1.6500	1.3200	1.1000	0.8250	0.6600	0.5500
29	27.3571	10.9428	9.1190	6.8393	5.4714	4.5595	3.4196	2.7357	2.2797	1.7098	1.3679	1.1399	0.8549	0.6840	0.5700
30	28.3994	11.3598	9.4665	7.0999	5.6799	4.7332	3.5499	2.8399	2.3666	1.7750	1.4200	1.1833	0.8875	0.7100	0.5917
31	29.3599	11.7440	9.7866	7.3400	5.8720	4.8933	3.6700	2.9360	2.4467	1.8350	1.4680	1.2234	0.9175	0.7340	0.6117
32	30.3995	12.1598	10.1332	7.5999	6.0799	5.0666	3.7999	3.0400	2.5333	1.9000	1.5200	1.2666	0.9500	0.7600	0.6333
33	31.3623	12.5449	10.4541	7.8406	6.2725	5.2271	3.9203	3.1363	2.6136	1.9602	1.5681	1.3068	0.9801	0.7841	0.6534
34	32.3995	12.9598	10.7998	8.0999	6.4799	5.3999	4.0499	3.2400	2.7000	2.0250	1.6200	1.3500	1.0125	0.8100	0.6750
35	33.3645	13.3458	11.1215	8.3411	6.6729	5.5608	4.1706	3.3365	2.7804	2.0853	1.6682	1.3902	1.0426	0.8341	0.6951
36	34.3996	13.7598	11.4665	8.5999	6.8799	5.7333	4.3000	3.4400	2.8666	2.1500	1.7200	1.4333	1.0750	0.8600	0.7167
37	35.3665	14.1466	11.7888	8.8416	7.0733	5.8944	4.4208	3.5366	2.9472	2.2104	1.7683	1.4736	1.1052	0.8842	0.7368
38	36.3996	14.5598	12.1332	9.0999	7.2799	6.0666	4.5500	3.6400	3.0333	2.2750	1.8200	1.5166	1.1375	0.9100	0.7583
39	37.3682	14.9473	12.4561	9.3421	7.4736	6.2280	4.6710	3.7368	3.1140	2.3355	1.8684	1.5570	1.1677	0.9342	0.7785
40	38.3997	15.3599	12.7999	9.5999	7.6799	6.4000	4.8000	3.8400	3.2000	2.4000	1.9200	1.6000	1.2000	0.9600	0.8000
41	39.3698	15.7479	13.1233	9.8425	7.8740	6.5616	4.9212	3.9370	3.2808	2.4606	1.9685	1.6404	1.2303	0.9842	0.8202
42	40.3997	16.1599	13.4666	10.0999	8.0799	6.7333	5.0500	4.0400	3.3666	2.5250	2.0200	1.6833	1.2625	1.0100	0.8417
43	41.3712	16.5485	13.7904	10.3428	8.2742	6.8952	5.1714	4.1371	3.4476	2.5857	2.0685	1.7238	1.2928	1.0343	0.8619
44	42.3998	16.9599	14.1333	10.6000	8.4800	7.0666	5.3000	4.2400	3.5333	2.6500	2.1200	1.7667	1.3250	1.0600	0.8833
45	43.3725	17.3490	14.4575	10.8431	8.6745	7.2288	5.4216	4.3373	3.6144	2.7108	2.1686	1.8072	1.3554	1.0843	0.9036
46	44.3998	17.7599	14.7999	11.1000	8.8800	7.4000	5.5500	4.4400	3.7000	2.7750	2.2200	1.8500	1.3875	1.1100	0.9250
47	45.3737	18.1495	15.1246	11.3434	9.0747	7.5623	5.6717	4.5373	3.7811	2.8338	2.2687	1.8905	1.4179	1.1343	0.9453
48	46.3999	18.5600	15.4666	11.6000	9.2800	7.7333	5.8000	4.6400	3.8667	2.9000	2.3200	1.9333	1.4500	1.1600	0.9667
49	47.3748	18.9499	15.7916	11.8437	9.4750	7.8958	5.9218	4.7375	3.9479	2.9609	2.3687	1.9739	1.5805	1.1844	0.9870
50	48.3999	19.3600	16.1333	12.1000	9.6800	8.0667	6.0500	4.8400	4.0333	3.0250	2.4200	2.0167	1.5125	1.2100	1.0083

[a] Pin diameter, $d_i = \frac{1.4400}{P}$.

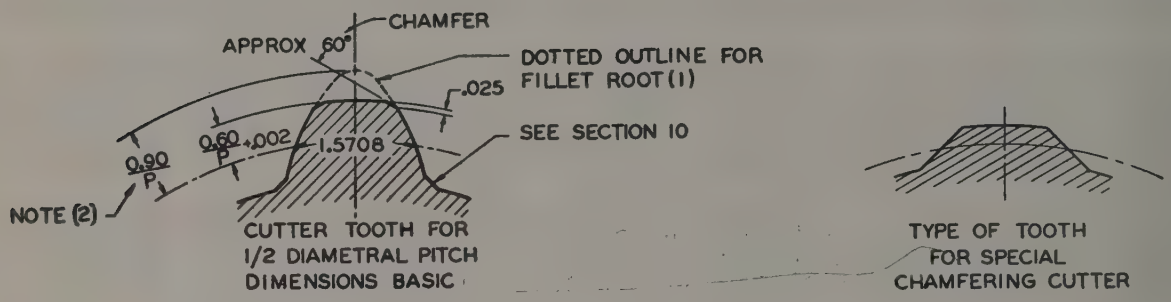
TABLE 29—*Basic Measurements Over Pins*[a]

N	DIAMETRAL PITCH														
	1/2	2.5/5	3/6	4/8	5/10	6/12	8/16	10/20	12/24	16/32	20/40	24/48	32/64	40/80	48/96
6	8.8660	3.5464	2.9553	2.2165	1.7732	1.4777	1.1083	0.8866	0.7388	0.5541	0.4433	0.3694	0.2771	0.2217	0.1847
7	9.6819	3.8728	3.2273	2.4205	1.9364	1.6137	1.2102	0.9682	0.8068	0.6051	0.4841	0.4034	0.3026	0.2421	0.2017
8	10.8944	4.3578	3.6315	2.7236	2.1789	1.8157	1.3618	1.0894	0.9079	0.6809	0.5447	0.4539	0.3405	0.2724	0.2270
9	11.7535	4.7014	3.9178	2.9384	2.3507	1.9589	1.4692	1.1754	0.9795	0.7346	0.5877	0.4897	0.3673	0.2938	0.2449
10	12.9144	5.1658	4.3048	3.2286	2.5829	2.1524	1.6143	1.2914	1.0762	0.8072	0.6457	0.5381	0.4036	0.3229	0.2690
11	13.8003	5.5201	4.6001	3.4501	2.7601	2.3001	1.7250	1.3800	1.1500	0.8625	0.6900	0.5750	0.4313	0.3450	0.2875
12	14.9295	5.9718	4.9765	3.7324	2.9859	2.4883	1.8662	1.4930	1.2441	0.9331	0.7465	0.6221	0.4665	0.3732	0.3110
13	15.8335	6.3334	5.2778	3.9584	3.1667	2.6389	1.9792	1.5834	1.3195	0.9896	0.7917	0.6597	0.4948	0.3958	0.3299
14	16.9412	6.7765	5.6471	4.2353	3.3882	2.8235	2.1177	1.6941	1.4118	1.0588	0.8471	0.7059	0.5294	0.4235	0.3529
15	17.8584	7.1434	5.9528	4.4646	3.5717	2.9764	2.2323	1.7858	1.4882	1.1162	0.8929	0.7441	0.5581	0.4465	0.3721
16	18.9507	7.5803	6.3169	4.7377	3.7901	3.1585	2.3688	1.8951	1.5792	1.1844	0.9475	0.7896	0.5922	0.4738	0.3948
17	19.8778	7.9511	6.6259	4.9695	3.9756	3.3130	2.4847	1.9878	1.6565	1.2424	0.9939	0.8282	0.6212	0.4970	0.4141
18	20.9584	8.3834	6.9861	5.2396	4.1917	3.4931	2.6198	2.0958	1.7465	1.3099	1.0479	0.8733	0.6550	0.5240	0.4366
19	21.8934	8.7574	7.2978	5.4734	4.3787	3.6489	2.7367	2.1893	1.8245	1.3683	1.0947	0.9122	0.6842	0.5473	0.4561
20	22.9649	9.1860	7.6550	5.7412	4.5930	3.8275	2.8706	2.2965	1.9137	1.4353	1.1482	0.9569	0.7177	0.5741	0.4784
21	23.9062	9.5625	7.9687	5.9766	4.7812	3.9844	2.9883	2.3906	1.9922	1.4941	1.1953	0.9961	0.7471	0.5977	0.4980
22	24.9704	9.9882	8.3235	6.2426	4.9941	4.1617	3.1213	2.4970	2.0809	1.5607	1.2485	1.0404	0.7803	0.6243	0.5202
23	25.9168	10.3667	8.6389	6.4792	5.1834	4.3195	3.2396	2.5917	2.1597	1.6198	1.2958	1.0799	0.8099	0.6479	0.5399
24	26.9752	10.7901	8.9917	6.7438	5.3950	4.4959	3.3719	2.6975	2.2479	1.6860	1.3488	1.1240	0.8430	0.6744	0.5620
25	27.9259	11.1704	9.3086	6.9815	5.5852	4.6543	3.4907	2.7926	2.3272	1.7454	1.3963	1.1636	0.8727	0.6982	0.5818
26	28.9793	11.5917	9.6598	7.2448	5.7959	4.8299	3.6224	2.8979	2.4149	1.8112	1.4490	1.2075	0.9056	0.7245	0.6037
27	29.9337	11.9735	9.9779	7.4834	5.9867	4.9890	3.7417	2.9934	2.4945	1.8709	1.4967	1.2472	0.9354	0.7483	0.6236
28	30.9829	12.3932	10.3276	7.7457	6.1966	5.1638	3.8729	3.0983	2.5819	1.9364	1.5491	1.2910	0.9682	0.7746	0.6455
29	31.9405	12.7762	10.6468	7.9851	6.3881	5.3234	3.9926	3.1941	2.6617	1.9963	1.5970	1.3309	0.9981	0.7985	0.6654
30	32.9862	13.1945	10.9954	8.2466	6.5972	5.4977	4.1233	3.2986	2.7489	2.0616	1.6493	1.3744	1.0308	0.8247	0.6872
31	33.9465	13.5786	11.3155	8.4866	6.7893	5.6578	4.2433	3.3947	2.8289	2.1217	1.6973	1.4144	1.0608	0.8487	0.7072
32	34.9890	13.9956	11.6630	8.7473	6.9978	5.8315	4.3736	3.4989	2.9158	2.1868	1.7495	1.4579	1.0934	0.8747	0.7289
33	35.9517	14.3807	11.9839	8.9879	7.1903	5.9920	4.4940	3.5952	2.9960	2.2470	1.7976	1.4980	1.1235	0.8988	0.7490
34	36.9916	14.7966	12.3305	9.2479	7.3983	6.1653	4.6240	3.6992	3.0826	2.3120	1.8496	1.5413	1.1560	0.9248	0.7707
35	37.9565	15.1826	12.6522	9.4891	7.5913	6.3261	4.7446	3.7957	3.1630	2.3723	1.8978	1.5815	1.1861	0.9489	0.7908
36	38.9939	15.5976	12.9980	9.7485	7.7988	6.4990	4.8742	3.8994	3.2495	2.4371	1.9497	1.6247	1.2186	0.9749	0.8124
37	39.9607	15.9843	13.3202	9.9902	7.9921	6.6601	4.9951	3.9961	3.3301	2.4975	1.9980	1.6650	1.2488	0.9990	0.8325
38	40.9960	16.3984	13.6653	10.2490	8.1992	6.8327	5.1245	4.0996	3.4163	2.5623	2.0498	1.7082	1.2811	1.0249	0.8541
39	41.9645	16.7858	13.9882	10.4911	8.3929	6.9941	5.2456	4.1965	3.4970	2.6228	2.0982	1.7485	1.3114	1.0491	0.8743
40	42.9980	17.1992	14.3327	10.7495	8.5996	7.1663	5.3748	4.2998	3.5832	2.6874	2.1499	1.7916	1.3437	1.0750	0.8958
41	43.9680	17.5872	14.6560	10.9920	8.7936	7.3280	5.4960	4.3968	3.6640	2.7480	2.1984	1.8320	1.3740	1.0992	0.9160
42	44.9996	17.9998	14.9999	11.2499	8.9999	7.4999	5.6245	4.5000	3.7500	2.8125	2.2500	1.8750	1.4062	1.1250	0.9375
43	45.9711	18.3884	15.3237	11.4928	9.1942	7.6619	5.7464	4.5971	3.8309	2.8732	2.2986	1.9155	1.4366	1.1493	0.9577
44	47.0013	18.8005	15.6671	11.7503	9.4003	7.8336	5.8752	4.7001	3.9168	2.9376	2.3501	1.9584	1.4688	1.1750	0.9792
45	47.9740	19.1896	15.9913	11.9935	9.5948	7.9957	5.9968	4.7974	3.9978	2.9984	2.3987	1.9989	1.4992	1.1994	0.9995
46	49.0028	19.6011	16.3343	12.2507	9.8006	8.1671	6.1253	4.9003	4.0836	3.0627	2.4501	2.0418	1.5313	1.2251	1.0209
47	49.9766	19.9906	16.6589	12.4942	9.9953	8.3294	6.2471	4.9977	4.1647	3.1235	2.4988	2.0824	1.5618	1.2494	1.0412
48	51.0041	20.4016	17.0014	12.7510	10.2008	8.5007	6.3755	5.1004	4.2503	3.1878	2.5502	2.1252	1.5939	1.2751	1.0626
49	51.9790	20.7916	17.3263	12.9948	10.3958	8.6632	6.4974	5.1979	4.3316	3.2487	2.5990	2.1658	1.6245	1.2995	1.0829
50	53.0054	21.2022	17.6685	13.2514	10.6011	8.8343	6.6257	5.3006	4.4171	3.3128	2.6503	2.2086	1.6564	1.3251	1.1043

[a] Pin diameter, $d_s = \frac{1.9200}{P}$

Appendix I

Special study will be required for internal spline teeth less than 10 for 2.5/5 through 6/12 diametral pitch, for less than 12 for 8/16 through 24/48, and for less than 16 for 32/64 through 48/96.

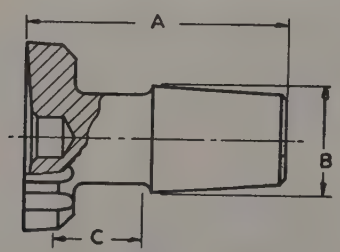


Note 1—Radius must satisfy specification of minimum radius given in Tables 5 through 19.
Note 2—For external splines, in diametral pitches of 16/32 through 48/96, the addendum is $1.00/P$.

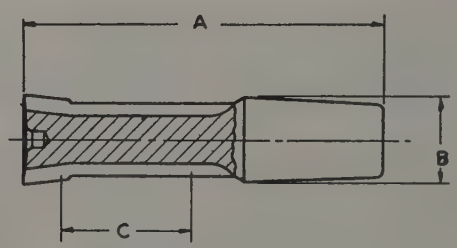
TABLE 30a—*Minimum Difference of Teeth, Internal Spline and Shaper Cutter*[a]

TYPE OF GEAR SHAPER	DIAMETRAL PITCH													
	2.5/5	3/6	4/8	5/10	6/12	8/16	10/20	12/24	16/32	20/40	24/48	32/64	40/80	48/96
#72 or #725A (standard backoff)	—	—	—	6	6	6	6	6	6	6	6	6	6	6
#6 or #6A (with special 0.010 backoff)	6	6	6	6	6	6	6	6	6	6	6	6	6	6
#6A (standard backoff)	10	10	10	10	10	9	8	7	7	7	7	7	7	7
#6 (standard backoff)	14	13	12	11	11	11	11	11	11	11	11	11	11	11

[a] For normal production conditions, the difference between numbers of teeth in work and cutter on internal splines should be not less than shown to avoid interference.



TAPER SHANK CUTTER FOR 2.5/5 & 3/6 DP

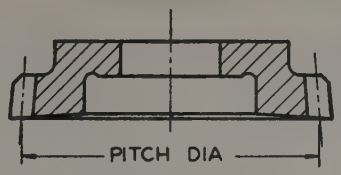


TAPER SHANK CUTTER FOR ALL EXCEPT 2.5/5 & 3/6 DP

TABLE 30b—*Cutter Dimensions of Smallest Shank, Internal Splines*[a]

DIAMETRAL PITCH	2.5/5	3/6	4/8	5/10	6/12	8/16	10/20	12/24	16/32	20/40	24/48	32/64	40/80	48/96
Number of teeth in cutter	4	4	4	4	4	5	6	6	6	7	7	9	10	12
A, Length	4.125	4.125	4.125	4.000	3.875	3.625	3.500	3.375	3.125	3.125	3.000	3.000	3.000	3.000
B, Taper diameter	1.063	1.063	1.063	1.063	1.063	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
C, Length of cut (at life)	2.000	2.000	1.750	1.625	1.500	1.375	1.250	1.125	1.000	1.000	0.875	0.875	0.750	0.750

[a] The smallest cutter in each diametral pitch as shown is the most versatile and will cut all but the smallest numbers of teeth. The taper-shank cutters are designed for the length of cut *C* given in the table. Where splines are designed to lengths not exceeding *C*, the availability of cutters from other users and manufacturers can expedite fabrication. The customer should specify whether cutters are to be made to these tables or for specific conditions.



DISC TYPE CUTTER

TABLE 30c—*Disc-Type Cutter Dimensions, External or Internal Splines*[a]

DIAMETRAL PITCH	2.5/5	3/6	4/8	5/10	6/12	8/16	10/20	12/24	16/32	20/40	24/48	32/64	40/80	48/96
Number of teeth in cutter	10	12	16	18	22	28	36	44	56	72	72	96	120	120
Pitch diameter of cutter	4.000	4.000	4.000	3.600	3.667	3.500	3.600	3.667	3.500	3.600	3.000	3.000	3.000	2.500
Approx min no. teeth in external if cut on shaper #6 or #6A	6	6	6	6	6	6	7	9	11	14	14	19	24	24
Approx min no. teeth in external if cut on shaper #72 or #725A	—	—	—	6	6	6	6	6	8	10	10	14	17	17

[a] Table 30c gives the number of teeth in preferred cutters for external and internal splines and is based on Table 30a.
When the 2.5-in. and 3.0-in. cutters are used on machines with cutter spindles larger than cutter-root (minor) diameter, the maximum face width will be limited by positioning of cutter on spindle. For 5/10 and finer diametral pitches, if type 62, 62A, or 7A machines are used, larger cutters with a 1.75-in. hole are required.

TABLE 30d—"*d*" *Disc-Type Preferred Cutters, Internal Splines*[a]

DIAMETRAL PITCH	2.5/5	3/6	4/8	5/10	6/12	8/16	10/20	12/24	16/32	20/40	24/48	32/64	40/80	48/96
	6	6	6	6	6	8	10	12	12	12	12	14	16	18
Number of teeth in cutters	8(d)	9(d)	8	10	9	12	15	18	18	24	24	24	24	24
	—	—	13(d)	16(d)	12	16	20	24	24	—	—	—	—	—
	—	—	—	—	18(d)	24(d)	30(d)	36(d)	—	—	—	—	—	—

[a] Table 30d shows the number of teeth in preferred cutters for internal splines and is based on Table 30a.
When 2.5-in. and 3.0-in. cutters are used on machines with cutter spindles larger than cutter-root (minor) diameter, the maximum face width will be limited by positioning of cutter on spindle. For 5/10 and finer diametral pitches, if type 62, 62A, or 7A machines are used, larger cutters with a 1.75-in. hole are required.

Appendix II

TABLE 31—*Recommended Dimensions for Hobs*

DIAMETRAL PITCH	OUTSIDE DIAMETER	WIDTH	BORE	DIAMETRAL PITCH	OUTSIDE DIAMETER	WIDTH	BORE
1/2	7.00	9.00	1.50	12/24	2.50	2.00	1.25
2.5/5	4.00	4.50	1.25	16/32	2.50	2.00	1.25
3/6	3.75	4.00	1.25	20/40	2.50	2.00	1.25
4/8	3.50	3.50	1.25	24/48	2.50	2.00	1.25
5/10	3.00	3.00	1.25	32/64	2.50	2.00	1.25
6/12	3.00	3.00	1.25	40/80	2.50	2.00	1.25
8/16	2.75	2.75	1.25	48/96	2.50	2.00	1.25
10/20	2.50	2.50	1.25				

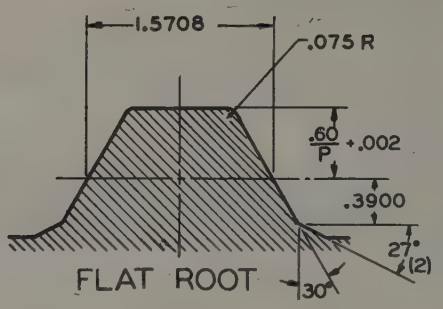
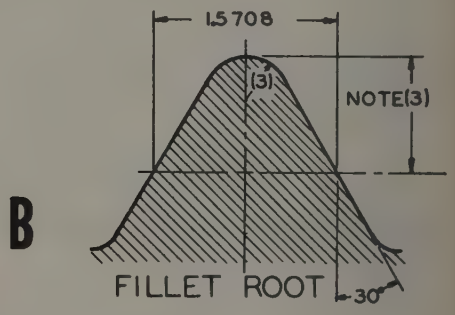


FIG. 8—1/2 DIAMETRAL PITCH, HOB TOOTH
Note 1—Hob shown in Fig. 8A should not be used for minor-diameter fits.
Note 2—Ramp is required for major-diameter fits (see Table 3) and also for the special combination covered by footnote c under "a" tables of Tables 5 through 19.
Note 3—The addendum of the hob is $0.90/P$ for diametral pitches from 1/2 through 12/24 and $1.00/P$ for diametral pitches from 16/32 through 48/96. The radius must be such as to satisfy specification of fillet radius in the tables.
Note 4—Depth of cut will vary as controlled to obtain the desired fit. See Tables 5 through 19.



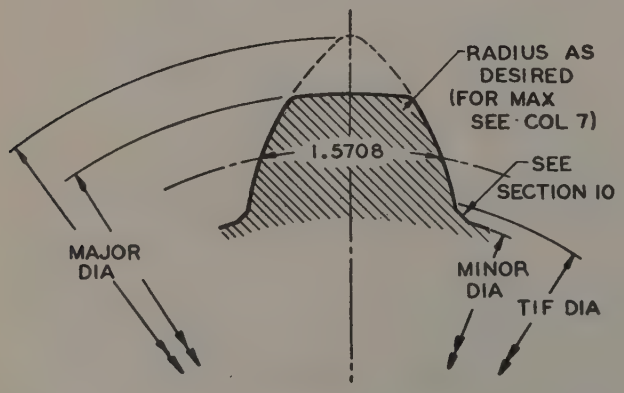


FIG. 9—1/2 DIAMETRAL PITCH, BROACH TOOTH
Note 1—The broach design will be in accordance with the specifications given in the tables for internal splines.
Note 2—The length of the broach is determined by the length of the part, the hardness, the type of material to be broached, and the broaching equipment available.
Note 3—The dotted outline shows the fillet-root type.

Appendix III

TABLE 32—*Special Basic Pin Measurements, Internal Spline Measurements with Round Pins Over 1.4400 Diameter*

N	AT PITCH POINT		NEAREST TO PITCH POINT				FIRST OVERSIZE PIN				SECOND OVERSIZE PIN		
	$30° - \frac{90°}{N}$	d_i[a]	d_i[b]	M_i	Clearance[c]	F	d_i[b]	M_i	Clearance[c]	F	d_i[b]	M_i	F
1	2	3	4	5	6	7	8	9	10	11	12	13	14
6	15.00000	1.6077	1.6080	3.7703	0.0068	3.58	—	—	—	—	—	—	—
7	17.14286	1.6301	1.6320	4.5465	0.0153	3.04	1.6800	4.2928	0.0968	—	—	—	—
8	18.75000	1.6482	1.6800	5.5304	0.0548	3.14	1.7040	5.4118	0.0901	3.80	—	—	—
9	20.00000	1.6631	1.6800	6.4387	0.0380	2.68	1.7040	6.3391	0.0644	2.90	—	—	—
10	21.00000	1.6756	1.6800	7.5842	0.0279	2.44	1.7040	7.4907	0.0506	2.58	—	—	—
11	21.81818	1.6863	1.6800	8.4934	0.0210	2.32	1.7040	8.4049	0.0416	2.41	—	—	—
12	22.50000	1.6954	1.6800	9.6083	0.0158	2.22	1.7040	9.5218	0.0351	2.29	1.7280	9.4333	2.37
13	23.07692	1.7033	1.6800	10.5266	0.0119	2.15	1.7040	10.4425	0.0302	2.21	1.7280	10.3568	2.28
14	23.57143	1.7102	1.6800	11.6225	0.0087	2.11	1.7040	11.5395	0.0262	2.15	1.7280	11.4551	2.21
15	24.00000	1.7163	1.6800	12.5493	0.0061	2.07	1.7040	12.4678	0.0230	2.11	1.7280	12.3851	2.15
16	24.37500	1.7217	1.7280	13.4692	0.0374	2.11	1.7520	13.3862	0.0549	2.15	—	—	—
17	24.70588	1.7266	1.7280	14.4054	0.0347	2.07	1.7520	14.3237	0.0517	2.11	—	—	—
18	25.00000	1.7310	1.7280	15.4790	0.0325	2.05	1.7520	15.3979	0.0490	2.08	—	—	—
19	25.26316	1.7349	1.7280	16.4206	0.0305	2.02	1.7520	16.3405	0.0467	2.05	—	—	—
20	25.50000	1.7385	1.7280	17.4863	0.0289	1.98	1.7520	17.4065	0.0447	2.03	1.7760	17.3260	2.05
21	25.71429	1.7418	1.7280	18.4327	0.0274	1.97	1.7520	18.3536	0.0430	2.01	1.7760	18.2739	2.03
22	25.90909	1.7448	1.7280	19.4919	0.0260	1.97	1.7520	19.4131	0.0415	1.99	1.7760	19.3337	2.01
23	26.08696	1.7476	1.7280	20.4425	0.0247	1.95	1.7520	20.3642	0.0401	1.97	1.7760	20.2854	1.99
24	26.25000	1.7502	1.7280	21.4964	0.0238	1.94	1.7520	21.4184	0.0388	1.96	1.7760	21.3398	1.98
25	26.40000	1.7525	1.7280	22.4505	0.0221	1.93	1.7520	22.3729	0.0377	1.95	1.7760	22.2948	1.97
26	26.53846	1.7547	1.7280	23.5001	0.0219	1.92	1.7520	23.4227	0.0366	1.94	1.7760	23.3448	1.95
27	26.66667	1.7568	1.7280	24.4574	0.0211	1.91	1.7520	24.3802	0.0358	1.93	1.7760	24.3027	1.94
28	26.78571	1.7587	1.7280	25.5031	0.0204	1.90	1.7520	25.4262	0.0349	1.92	1.7760	25.3489	1.93
29	26.89655	1.7605	1.7280	26.4630	0.0197	1.89	1.7520	26.3864	0.0341	1.91	1.7760	26.3094	1.92
30	27.00000	1.7621	1.7280	27.5057	0.0191	1.89	1.7520	27.4292	0.0334	1.90	1.7760	27.3523	1.92
31	27.09677	1.7637	1.7280	28.4682	0.0185	1.88	1.7520	28.3918	0.0328	1.89	1.7760	28.3152	1.91
32	27.18750	1.7652	1.7280	29.5079	0.0180	1.88	1.7520	29.4318	0.0321	1.89	1.7760	29.3552	1.90
33	27.27273	1.7666	1.7280	30.4725	0.0176	1.87	1.7520	30.3964	0.0316	1.88	1.7760	30.3202	1.89
34	27.35294	1.7679	1.7280	31.5098	0.0171	1.87	1.7520	31.4340	0.0310	1.88	1.7760	31.3578	1.89
35	27.42857	1.7691	1.7280	32.4761	0.0166	1.86	1.7520	32.4005	0.0305	1.87	1.7760	32.3245	1.88
36	27.50000	1.7703	1.7280	33.5115	0.0162	1.86	1.7520	33.4359	0.0300	1.87	1.7760	33.3600	1.88
37	27.56757	1.7714	1.7280	34.4797	0.0158	1.85	1.7520	34.4042	0.0296	1.86	1.7760	34.3284	1.87
38	27.63158	1.7725	1.7280	35.5130	0.0155	1.85	1.7520	35.4376	0.0292	1.86	1.7760	35.3619	1.87
39	27.69231	1.7735	1.7280	36.4827	0.0150	1.85	1.7520	36.4074	0.0288	1.86	1.7760	36.3317	1.87
40	27.75000	1.7745	1.7280	37.5143	0.0148	1.84	1.7520	37.4391	0.0284	1.85	1.7760	37.3637	1.86
41	27.80488	1.7754	1.7280	38.4855	0.0145	1.84	1.7520	38.4103	0.0282	1.85	1.7760	38.3350	1.86
42	27.85714	1.7763	1.7280	39.5155	0.0142	1.84	1.7520	39.4405	0.0277	1.85	1.7760	39.3652	1.85
43	27.90698	1.7771	1.7280	40.4877	0.0140	1.83	1.7520	40.4129	0.0274	1.84	1.7760	40.3378	1.85
44	27.95455	1.7779	1.7280	41.5166	0.0138	1.83	1.7520	41.4417	0.0271	1.84	1.7760	41.3666	1.85
45	28.00000	1.7787	1.7280	42.4901	0.0136	1.83	1.7520	42.4153	0.0269	1.84	1.7760	42.3404	1.85
46	28.04348	1.7794	1.7280	43.5175	0.0132	1.83	1.7520	43.4428	0.0266	1.84	1.7760	43.3679	1.85
47	28.08511	1.7801	1.7280	44.4921	0.0130	1.82	1.7520	44.4175	0.0263	1.83	1.7760	44.3427	1.84
48	28.12500	1.7808	1.7280	45.5184	0.0128	1.82	1.7520	45.4438	0.0261	1.83	1.7760	45.3690	1.84
49	28.16327	1.7814	1.7280	46.4942	0.0126	1.82	1.7520	46.4195	0.0259	1.83	1.7760	46.3448	1.84
50	28.20000	1.7821	1.7280	47.5192	0.0124	1.82	1.7520	47.4447	0.0256	1.83	1.7760	47.3700	1.84

[a] $d_i = D_b \left[\text{Inv } 30° + \frac{t_s}{D} - \text{Inv} \left(30° - \frac{90°}{N} \right) \right]$

[b] Pins given are commercial sizes.

[c] Clearance with major diameter, (Col 4, Table 5): with N even, clearance $= \frac{(N+1) - (M_i + 2d_i)}{2}$; with N odd, clearance $= 0.5\,(N+1) - d_i - \frac{M_i + d_i}{\cos \frac{90°}{N}}$

Appendix IV—Engineering Suggestions

General—Some of the advantages of involute splines with 30 deg pressure angle are:

1. Tooth has maximum strength through the minor diameter where needed.
2. Involute splines are self centering and therefore tend to equalize the bearing and stresses among all the teeth.
3. Because of the generating action of the hobbing operation, a smooth tooth surface is obtained; therefore, it is not normally necessary to grind a splined part on the involute curve.
4. Cutting tools are readily manufactured and checked.

Length of Spline—For carrying of any load or to obtain stability, there is seldom need to have a spline longer than its pitch diameter.

Torque Capacity—Formulas (7) through (13) will apply to most splined shafts.

Q = torsional moment, inch pounds
S_s = allowable torsional shear stress, pounds per square inch
S_c = allowable compressive bearing stress, pounds per square inch
D_i = inside diameter of hollow shaft
A_t = area of one tooth in contact
L = length of spline, inches
h = height of contact on tooth = $0.8/P = 0.8D/N$ (0.80 is a minimum)

The customary expression for torsional resistance of a shaft of diameter D_R is

$$Q = \frac{\pi D_R^3 S_s}{16} \tag{7a}$$

or

$$S_s = \frac{16Q}{\pi D_R^3} \tag{7b}$$

Assuming that all teeth are contacting, we may write the equation

$$Q = \frac{S_c A_t N D}{2}$$

and since

$$A_t = Lh = \frac{0.8\,LD}{N}$$

then

$$Q = \frac{S_c L D^2}{2.5} \tag{8a}$$

or

$$L = \frac{2.5Q}{S_c D^2} \tag{8b}$$

or

$$S_c = \frac{2.5Q}{LD^2} \tag{8c}$$

For shear stress at the pitch diameter (which averages for internal and external splines), the area in shear is π DL/2, or 1.5708 DL; therefore, the spline shear stress is

$$S_s = \frac{2Q}{D(1.5708DL)} = \frac{1.2732Q}{LD^2} \tag{9a}$$

$$L = \frac{1.2732Q}{S_s D^2} \tag{9b}$$

By dividing (9a) by (8c), we can obtain a ratio of S_s/S_c of 0.5093. Good practice dictates that the allowable shear stress be taken as 60% and the allowable compressive bearing stress as 140% of the tensile ultimate stress, or a ratio of 60/140, or 0.428. The design of splines is therefore critical in shear.

By combining (9a) and (7a), which involve only shear stress, we obtain

$$L = 0.250\,\frac{D_R^3}{D^2} \tag{10}$$

which applies only under ideal conditions with all teeth in perfect contact. Actual practice has shown that because of inaccuracies in spacing and tooth form, the equivalent of about 25% of teeth contact, so that a good approximate formula for a splined solid shaft is

$$L = \frac{D_R^4}{D^3} \tag{11}$$

By similar combinations, we can obtain, for hollow shafts, the formula

$$L = \frac{D_R^4 - D_i^4}{4D^3 D_R} \tag{12}$$

and adjusting for 25% contact as in (11), we obtain

$$L = \frac{D_R^4 - D_i^4}{D^3 D_R} \tag{13}$$

Appendix V—Derivation of Factors E and F

External Spline Factor E—The original position of pin is shown in dotted lines in Fig. 10, and the secondary position taken when t has been decreased is shown in solid lines. Involutes are drawn through the pin center and are parallel, and x on the base circle is equal to the side opposite ϕ_e in the small triangle at the pin center, therefore

$$X = \frac{\Delta M_e}{2} \sin \phi_e \text{ (approximate)}$$

x at the pitch circle forms an angle with the tangent where Δt measurement applies, therefore

$$\frac{\Delta t}{2} = \frac{X}{\cos \phi} = \frac{\Delta M_e \sin \phi_e}{2 \cos \phi}$$

N even,

$$\frac{\Delta M_e}{\Delta t} = \frac{\cos \phi}{\sin \phi_e} = E$$

N odd,

$$E = \frac{\cos \phi}{\sin \phi_e} \cos \frac{90°}{N}$$

Example:

$P = 8/16, N = 20, t = 0.1923$
$\Delta t = t_e - t = 0.1963 - 0.1923 = 0.0040$
$M_e = 2.8706$ (Table 29) $\quad E = 1.525$ (Table 4, Col 11)
$\Delta M_e = 1.525 \times 0.0040 = 0.0061$
$M_x = M_e - \Delta M_e = 2.8706 - 0.0061 = 2.8645$

Internal Spline Factor F—The original position of pin is shown in solid lines in Fig. 11 and the secondary position taken then t_e has been increased is shown in dotted lines. Involutes are drawn through the pin center and are parallel, and x on the base circle is equal to the side opposite ϕ_i in the small triangle at the pin center, therefore

N even,

$$\frac{\Delta M_i}{\Delta t_e} = \frac{\cos \phi}{\sin \phi_i} = F$$

N odd,

$$F = \frac{\cos \phi}{\sin \phi_i} \cos \frac{90°}{N}$$

Example:

$P = 8/16, N = 20, t_x = t_e + 0.0020$
$M_i = 2.2998$ (Table 28)
$M_x = 2.2998 + (0.0020 \times 1.78) = 2.3034$

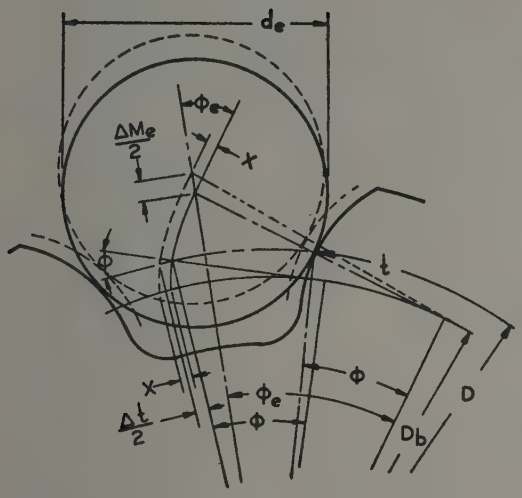


Fig. 10—Pin Positions, External Spline

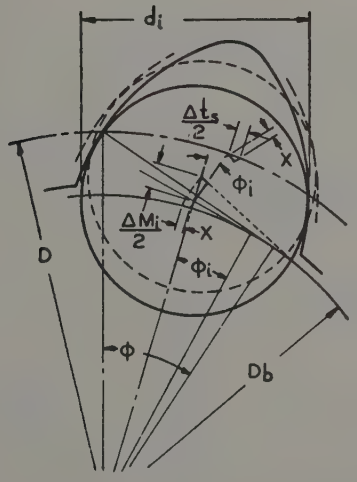


Fig. 11—Pin Positions, Internal Spline

Appendix VI

TABLE 33—*Spline Selections for Ball Bearings*[a]

BEARING BORE		DIAMETRAL PITCH																									
		2.5/5		3/6		4/8		5/10		6/12		8/16		10/20		12/24		16/32		20/40		24/48		32/64		40/80		48/96	
Mm	Inches	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam	*N*	Diam
—	0.1900	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.175	8	0.188
—	0.2500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.219	8	0.225	10	0.229
—	0.3125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.292	8	0.281	11	0.300	13	0.292
—	0.3750	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.350	7	0.333	10	0.344	13	0.350	16	0.354
10	0.3937	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.350	8	0.375	11	0.375	14	0.375	17	0.375
12	0.4724	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.438	8	0.450	10	0.458	14	0.469	17	0.450	21	0.458
—	0.5000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.438	8	0.450	10	0.458	14	0.469	18	0.475	22	0.479
15	0.5906	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.583	8	0.563	10	0.550	13	0.583	17	0.563	22	0.575	27	0.583
—	0.6250	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	0.583	8	0.563	11	0.600	13	0.583	18	0.594	23	0.600	28	0.604
17	0.6693	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	0.667	9	0.625	12	0.650	15	0.667	20	0.656	25	0.650	31	0.667
—	0.7500	—	—	—	—	—	—	—	—	—	—	—	—	6	0.700	7	0.667	10	0.688	13	0.700	16	0.708	22	0.719	28	0.725	34	0.729
20	0.7874	—	—	—	—	—	—	—	—	—	—	—	—	6	0.700	8	0.750	11	0.750	14	0.750	17	0.750	24	0.781	30	0.775	36	0.771
25	0.9843	—	—	—	—	—	—	—	—	—	—	6	0.875	8	0.900	10	0.917	14	0.938	18	0.950	22	0.958	30	0.969	38	0.975	46	0.979
—	1.0000	—	—	—	—	—	—	—	—	—	—	6	0.875	8	0.900	10	0.917	14	0.938	18	0.950	22	0.958	30	0.969	38	0.975	46	0.979
30	1.1811	—	—	—	—	—	—	—	—	6	1.167	8	1.125	10	1.100	13	1.167	17	1.125	22	1.150	27	1.167	36	1.156	46	1.175	55	1.167
—	0.2500	—	—	—	—	—	—	—	—	6	1.167	8	1.125	11	1.200	13	1.167	18	1.188	23	1.200	28	1.208	38	1.219	48	1.225	58	1.229
—	0.3130	—	—	—	—	—	—	—	—	6	1.167	9	1.250	12	1.300	14	1.250	19	1.250	25	1.300	30	1.292	40	1.281	51	1.300	61	1.292
35	1.3780	—	—	—	—	—	—	—	—	7	1.333	10	1.375	12	1.300	15	1.333	21	1.375	26	1.350	32	1.375	43	1.375	54	1.375	65	1.375
—	1.4380	—	—	—	—	—	—	—	—	7	1.333	10	1.375	13	1.400	16	1.417	21	1.375	27	1.400	33	1.417	44	1.406	56	1.425	67	1.417
—	1.5630	—	—	—	—	—	—	—	—	8	1.500	11	1.500	14	1.500	17	1.500	23	1.500	30	1.550	36	1.542	48	1.541	61	1.550	73	1.542
40	1.5748	—	—	—	—	—	—	6	1.400	8	1.500	11	1.500	14	1.500	17	1.500	24	1.563	30	1.550	36	1.542	49	1.563	61	1.550	74	1.563
45	1.7717	—	—	—	—	6	1.750	7	1.600	9	1.667	13	1.750	16	1.700	20	1.750	27	1.750	34	1.750	41	1.750	55	1.750	69	1.750	83	1.750
—	1.8130	—	—	—	—	6	1.750	8	1.800	9	1.667	13	1.750	17	1.800	20	1.750	27	1.750	35	1.800	42	1.792	56	1.781	71	1.800	85	1.792
50	1.9685	—	—	—	—	6	1.750	8	1.800	10	1.833	14	1.875	18	1.900	22	1.917	30	1.938	38	1.950	46	1.958	62	1.968	77	1.950	93	1.958
—	2.0630	—	—	—	—	7	2.000	9	2.000	11	2.000	15	2.000	19	2.000	23	2.000	31	2.000	40	2.050	48	2.042	64	2.031	81	2.050	97	2.042
55	2.1654	—	—	—	—	7	2.000	9	2.000	11	2.000	16	2.125	20	2.100	24	2.083	33	2.125	42	2.150	50	2.125	68	2.156	85	2.150	—	—
—	2.3130	—	—	—	—	8	2.250	10	2.200	12	2.167	17	2.250	22	2.300	26	2.250	35	2.250	45	2.300	54	2.292	72	2.281	91	2.300	—	—
60	2.3622	—	—	6	2.333	8	2.250	10	2.200	13	2.333	17	2.250	22	2.300	27	2.333	36	2.313	46	2.350	55	2.333	74	2.343	93	2.350	—	—
65	2.5591	—	—	6	2.333	9	2.500	11	2.400	14	2.500	19	2.500	24	2.500	29	2.500	39	2.500	50	2.550	60	2.542	80	2.531	—	—	—	—
70	2.7559	—	—	7	2.667	10	2.750	12	2.600	15	2.667	21	2.750	26	2.700	32	2.750	43	2.750	54	2.750	65	2.750	87	2.750	—	—	—	—
—	2.9380	6	2.800	7	2.667	10	2.750	13	2.800	16	2.833	22	2.900	28	2.900	34	2.917	45	2.875	57	2.900	69	2.917	92	2.906	—	—	—	—
75	2.9528	6	2.800	7	2.667	10	2.750	13	2.800	16	2.833	22	2.875	28	2.900	34	2.917	46	2.938	58	2.950	69	2.917	93	2.938	—	—	—	—
—	3.0630	6	2.800	8	3.000	11	3.000	14	3.000	17	3.000	23	3.000	29	3.000	35	3.000	47	3.000	60	3.050	72	3.042	96	3.031	—	—	—	—
80	3.1496	6	2.800	8	3.000	11	3.000	14	3.000	17	3.000	24	3.125	30	3.100	36	3.083	49	3.125	61	3.100	74	3.125	99	3.125	—	—	—	—
85	3.3465	7	3.200	9	3.333	12	3.250	15	3.200	19	3.333	25	3.250	32	3.300	39	3.333	52	3.313	65	3.300	79	3.333	—	—	—	—	—	—
90	3.5433	7	3.200	9	3.333	13	3.500	16	3.400	20	3.500	27	3.500	34	3.500	41	3.500	55	3.500	69	3.500	83	3.542	—	—	—	—	—	—
95	3.7402	8	3.600	10	3.667	13	3.500	17	3.600	21	3.667	28	3.625	36	3.700	43	3.667	58	3.688	73	3.700	88	3.708	—	—	—	—	—	—
100	3.9370	8	3.600	10	3.667	14	3.750	18	3.800	22	3.833	30	3.875	38	3.900	46	3.917	61	3.875	77	3.900	93	3.917	—	—	—	—	—	—
105	4.1339	9	4.000	11	4.000	15	4.000	19	4.000	23	4.000	32	4.125	40	4.100	48	4.083	65	4.125	81	4.100	98	4.125	—	—	—	—	—	—
110	4.3307	9	4.000	11	4.000	16	4.250	20	4.200	24	4.167	33	4.250	42	4.300	50	4.250	68	4.312	85	4.300	—	—	—	—	—	—	—	—
120	4.7244	10	4.400	13	4.667	17	4.500	22	4.600	27	4.667	36	4.625	46	4.700	55	4.667	74	4.688	93	4.700	—	—	—	—	—	—	—	—
130	5.1181	11	4.800	14	5.000	19	5.000	24	5.000	29	5.000	39	5.000	50	5.100	60	5.083	80	5.062	—	—	—	—	—	—	—	—	—	—
140	5.5118	12	5.200	15	5.333	21	5.500	26	5.400	32	5.500	43	5.500	54	5.500	65	5.500	87	5.500	—	—	—	—	—	—	—	—	—	—
150	5.9055	13	5.600	16	5.667	22	5.750	28	5.800	34	5.833	46	5.875	58	5.900	69	5.833	93	5.875	—	—	—	—	—	—	—	—	—	—
160	6.2992	14	6.000	17	6.000	24	6.250	30	6.200	36	6.167	49	6.250	61	6.200	74	6.250	99	6.250	—	—	—	—	—	—	—	—	—	—
170	6.6929	15	6.400	19	6.667	25	6.500	32	6.600	39	6.667	52	6.625	65	6.600	79	6.667	—	—	—	—	—	—	—	—	—	—	—	—
180	7.0866	16	6.800	20	7.000	27	7.000	34	7.000	41	7.000	55	7.000	69	7.000	84	7.083	—	—	—	—	—	—	—	—	—	—	—	—
190	7.4803	17	7.200	21	7.333	28	7.250	36	7.400	43	7.333	58	7.375	73	7.400	88	7.417	—	—	—	—	—	—	—	—	—	—	—	—
200	7.8740	18	7.600	22	7.667	30	7.750	38	7.800	46	7.833	61	7.750	77	7.800	93	7.833	—	—	—	—	—	—	—	—	—	—	—	—
210	8.2677	19	8.000	23	8.000	32	8.250	40	8.200	48	8.167	65	8.250	81	8.200	98	8.250	—	—	—	—	—	—	—	—	—	—	—	—
220	8.6614	20	8.400	24	8.333	33	8.500	42	8.600	50	8.500	68	8.625	85	8.600	—	—	—	—	—	—	—	—	—	—	—	—	—	—
230	9.0551	21	8.800	26	9.000	35	9.000	44	9.000	53	9.000	71	9.000	89	9.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—
240	9.4488	22	9.200	27	9.333	36	9.250	46	9.400	55	9.333	74	9.375	93	9.400	—	—	—	—	—	—	—	—	—	—	—	—	—	—
250	9.8425	23	9.600	28	9.667	38	9.750	48	9.800	58	9.833	77	9.750	97	9.800	—	—	—	—	—	—	—	—	—	—	—	—	—	—
260	10.2362	24	10.000	29	10.000	39	10.000	50	10.200	60	10.167	80	10.125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
280	11.0236	26	10.800	32	11.000	43	11.000	54	11.000	65	11.000	87	11.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
320	12.5984	30	12.400	36	12.333	49	12.500	61	12.400	74	12.500	99	12.500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[a] Dimensions given are number of teeth and major diameters nearest under bearing bore.

Appendix VII—Taper Applications

Splines with Tapered Minor Diameter—One of the special applications is a minor-diameter fit, where the minor diameter is machined on a taper, to obtain tight fits which are also readily removable. In all such applications, the dimensions in the Standard should be used for the large end of the tapered internal-spline fitting. Figs. 12, 13, and 14 show the assembly and the two splined members.

Internal Spline—The dimensions in Col 39 are basic, but since the fit in this case is not on the cylindrical minor diameter, use Col 6 for the minor diameter with the tolerance from Col 37. Use Col 9A for the major diameter. No chamfers are needed. Use Col 10 for *TIF* diameter and col 14 for the pin measurements.

External Spline—Use dimensions in Col 21 with tolerance from Col 39 for taper applications. Use Col 24 for major diameter. Pin measurements from either Col 28 or 29 may be used, but Col 29 is suggested as desirable for close fits. Use Col 27 for *TIF* diameter.

General—For both internal and external members, use Col 2 and 3 for the dimensions at the large end of the internal spline, and the entering end of the external spline.

Taper—The magnitude of the taper is dependent on the necessity of easy removal or the desire for a permanent fit. The length of the hub and the diametral pitch best suited for the design will also influence the selection of the taper.

A taper of 3 in. per ft (included angle) is recommended for parts that must be easily removed. A taper of 1.5 in. per ft (included angle) will develop maximum strength. A straight land (*B* in Fig. 14) is desirable, in the processing of the internal spline, for a tool guide as well as for gaging. A basic plane, located at the basic diameter of the taper, may be used to set up a tolerance dimension to a critical shoulder on the shaft as well as a critical face on the hub.

The dimensions for the land and spline length are easily calculated by using the ratio of the length to the depth of half the included angle of the taper.

Taper per foot	1.5	2.00	3.00	4.00
Ratio	16	12	8	6

$$L = \left(\frac{\text{Col 4} - \text{Col 21}}{2} \times \text{ratio}\right) + \text{draw}$$

$$L - B = \left(\frac{\text{Col 4} - \text{Col 6}}{2} \times \text{ratio}\right)$$

$$B = \left(\frac{\text{Col 6} - \text{Col 21}}{2} \times \text{ratio}\right) + \text{draw}$$

Tools—The same broach required for involute splines will also be used for tapered splines. The neck of the broach must be processed with proper tolerance for a precision sliding fit in the straight or land portion of the taper hole. The shaping tools for straight splines are applicable for the tapered type.

Hobs are made for the tapered minor diameter, based on the 30-deg pressure angle involute form, and they will correctly cut a spline of any standard pitch diameter and any conventional included angle.

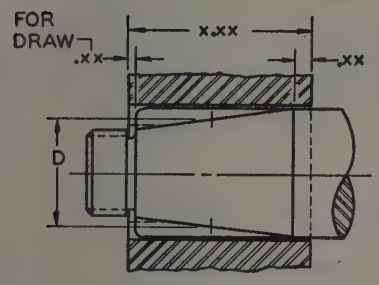


Fig. 12—Taper Assembly

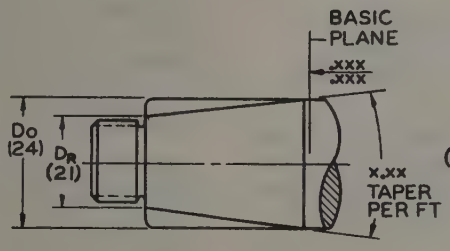


Fig. 13—Taper, External Spline

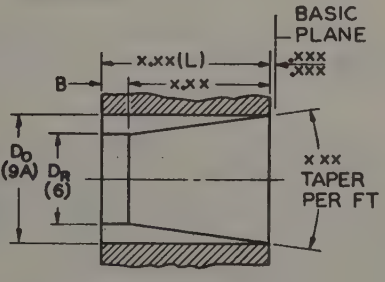


Fig. 14—Taper, Internal Spline

Involute Serrations

SAE Standard

Report of Parts and Fittings Division approved August 1922 and last revised by Parts and Fittings Technical Committee January 1950. This SAE Standard conforms with American Standard for Involute Serrations, ASA B5.26-1950.

[*This SAE Standard and American Standard ASA B5.26–1950 are in accord with the exception of the system of numbering the tables; the numbers of corresponding tables in the two standards are given below.*

Corresponding Tables

Title	*SAE*	*Amer Std*
Tooth Dimensions	1	1
Allowable Errors	2	2
Basic Data	3	3
10/20 Diametral Pitch	4	4, 5
16/32 Diametral Pitch	5	6, 7
24/48 Diametral Pitch	6	8, 9
32/64 Diametral Pitch	7	10
40/80 Diametral Pitch	8	11
48/96 Diametral Pitch	9	12
64/128 Diametral Pitch	10	13
80/160 Diametral Pitch	10	13
128/256 Diametral Pitch	10	13
Internal Serration, Maximum Space Width	11	14
Basic Measurements, Internal	12	15
External Serration, Minimum Tooth Thickness	13	16
Basic Measurements, External	14	17
Hob Dimensions	15	18
Angle A	16	19

All figures are the same in both standards although SAE Figs. 2, 3, 4, and 5 are ASA Figs. 4, 5, 2, and 3, respectively.]

Key to Abbreviations

Circ—Circular	*Int—Internal*	*R; Rad—Radius*
Col—Column	*Inv—Involute*	*Ref—Reference*
Ext—External	*Meas—Measurement*	*TIF—True Involute Form*

1. **Definition and Scope**—Involute serrations are multiple keys in the general form of internal and external involute gear teeth, used for permanent fits between shafts and parts mounted thereon. The purpose of this standard is to provide a uniform, easily fabricated set of serrations that can be made by several manufacturing processes.

The pitches included are 10/20, 16/32, 24/48, 32/64, 40/80, 48/96, 64/128, 80/160, and 128/256, complete from 6 to 100 teeth only for the first three. The scope is from 0.10 diameter to 10.00 diameter.

2. **Nomenclature**—The nomenclature (Fig. 1) agrees as nearly as possible with that adopted by the American Gear Manufacturers Association and the American Standards Association and corresponds exactly with the SAE Standard for Involute Splines.

3. **Pressure Angle**—The pressure angle for all serrations is 45 deg.

4. **Basic Tooth Form**—All serrations are based upon involute form as generated with a straight-sided hob of the form included in this standard.[1]

5. **Tooth Dimensions**—The basic dimensions are diametral pitch, pitch diameter, circular pitch, major diameter (of external serration), minor diameter (of external serration), and addendum (of external serration). (See Tables 1 and 2)

The special dimensions are circular tooth thickness and width of space and both major and minor diameter of the internal serration.

The dimensions for the internal serration are held the same for all fits, and the external serration is varied to obtain the desired fit.

Modifications are made to obtain equally strong teeth in both members and at the same time retain even steps of major diameter in ordinary fractions.

6. **Basic Formulas**

Pitch diameter, $D = \frac{N}{P}$

Circular pitch, $p = \frac{\pi}{P}$

Major diameter, external, $D_O = \frac{N + 1}{P}$

Minor diameter, external, $D_R = \frac{N - 1}{P}$

True involute-form diameter, internal, $TIF = \frac{N + 1.10}{P}$

True involute-form diameter, external, $TIF = \frac{N - 0.70}{P}$

Major diameter, internal, $D_O = \frac{N + 1.40}{P}$

Minor diameter, internal, $D_R = \frac{N - 0.60}{P}$

Addendum, external, a } $= \frac{0.500}{P}$
Dedendum, external, b }

Addendum, internal, $a_1 = \frac{0.300}{P}$

Dedendum, internal, $b_1 = \frac{0.700}{P}$

Circular space width, internal, $t_s = \frac{0.5\pi + 0.20}{P}$

7. **Tables**—Table 3 shows basic dimensions from which the dimensions for any serration may be calculated. Some of the data apply equally to all diametral pitches, and some must be divided by the diametral pitch for direct use.

Tables 4 to 10 inclusive show all dimensions for three classes of fits. All dimensions are inversely proportional to diametral pitch, except measurement over pins for the external serrations and tolerances given at the heading of the columns.

Table dimensions have been rounded off by using the last figure (fourth place) retained unchanged if that which follows

[1] In internal serrations for fine diametral pitches, particularly with a large number of teeth, the involute curve will approach a straight line, and a straight profile is acceptable in this Standard. (See Appendix II)

Dimensional and Effective Clearances for 25 Teeth[a]

DIAMETRAL PITCH	CLASS A			CLASS B			CLASS C		
	Dimensional	Effective clearance		Dimensional	Effective clearance		Dimensional	Effective clearance	
	Max	Min	Max	Max	Min	Max	Max	Min	Max
10/20	0.0067	0.0005	0.0030	0.0052	−0.0010	0.0015	0.0032	−0.0030	−0.0005
16/32	0.0065	0.0005	0.0030	0.0050	−0.0010	0.0015	0.0030	−0.0030	−0.0005
24/48 up	0.0059	0.0005	0.0025	0.0044	−0.0010	0.0010	0.0024	−0.0030	−0.0010

[a] Based on using 60% of all allowable errors cumulatively, not including lead.

is less than 5, and increasing the last figure (fourth place) to the next larger when the following figure is 5 or more.

All dimensions are in inches.

.8 **Measurement of Tooht Thickness**—Tooth thickness is determined by measuring over pins for the external and between pins for the internal serrations. The diameter of the pins is optional within a narrow range. It is not necessary that a pin contact exactly at the pitch circle. For the sake of uniformity and to follow a satisfactory practice, this standard incorporates a recommended pin diameter indicated at the top of each table. Measurements with pins will not check spacing errors, and these must be determined by other means.

9. **Classes of Fits**—There are three classes of fit: loose, close, and press. These are designated in the Standard as Classes A, B, and C respectively.

10. **Fillets**

External Serration—The fillet for the minor diameter is formed by the generating action of the hob or shaper cutter. In the heading for each table will be found the radius recommended for the cutting tool. The resulting fillet will not be a true radius and will always be larger than that of the tool.

Internal Serrations—The radius of tool given in the table is recommended for use on the broach. The same radius, if used on a shaper cutter, will form a fillet which will not be a true radius and will always be larger than that of the cutter.

11. **Measurements With Pins**—In Figs. 2 and 3 are given the formulas and methods used for calculating measurements over pins for external serrations and between pins for internal serrations. (See also Section 19)

12. **Drawings**—It is important that uniform methods be used to show complete information on detail drawings. Figs. 4 and 5 show the sections recommended, the placing of dimensions, and the involute-serration data required. Much trouble may be avoided by following this in detail.

13. **Tooth Spacing Errors**—Errors of spacing should be checked with machines made for that purpose or checked with gages. (See also Sections 16 and 20)

14. **Cutters**—Figs. 6, 7, and 8 show dimensions for hob, broach, and cutter teeth. These dimensions should be divided by the diametral pitch being used.

15. **Standard Fits (Effective)**—The effective space width of the internal serration is equal to the dimensional space width minus a portion of the total of all the allowable errors, and likewise the effective tooth thickness of the external serration is equal to the dimensional tooth thickness plus a portion of the total of all the allowable errors. (See Section 20)

The effective clearance (positive or negative) between the two serrated parts is equal to the effective space width of the internal serration minus the effective tooth thickness of the external serration. The sign (−) indicates an interference.

Tolerances in the tables are for a complete gaging system. For pin measurement and instrument checking, calculate as directed in Section 22.

16. **Tolerances**—In the cutting of a serrated part, a machine-tool adjustment may vary the depth of cut and therefore the tooth thickness. The acceptable tolerance amounts are listed in Table 2. For any fit, the tolerances are added to the allowable-error total (see Section 22) in the calculation of space width and tooth thickness. The total of tolerance and errors provide the range for the manufacture of tools and gages.

The fits and tolerance suggested in this standard are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.

17. **Special Fits**—When fits other than those given in the tables are required, proceed as follows:

(a)—Subtract (algebraically) the desired minimum clearance from basic tooth thickness. This will be *maximum*.

(b)—Add (algebraically) the desired minimum clearance to the value[2] 0.0017. Add to this amount the machining tolerance from Table 2.

(c)—Substitute the result of (b), in ten thousandths, for the second figure in parenthesis in the appropriate formula, Section 22, and calculate tooth thickness. This will be *minimum*.

(d)—Multiply result of (b) by factor[3] E, and deduct product from appropriate basic pin measurement, Table 14. Result will be minimum measurement over pins.

18. **Tapered Serrations**—The dimensions in this Standard should apply to the big end of the external or shaft and the big end of the internal or fitting. The degree of taper recommended is 0.750 in. per ft included angle, measured on the major diameter (see Fig. 9).

19. **Pin Measurements**—For internal serrations, minimum pin measurements are not specified because they should not be the basis for rejection as long as effective size, controlled by gages, is not below the specified minimum. When it is not feasible to check effective sizes, a minimum pin measurement may be used equal to the maximum pin measurement minus the machining tolerance (Table 2) times factor[3] F. This minimum pin measurement may, however, be reduced as allowable errors are reduced.

For external serrations, maximum pin measurements are not specified for the same reasons as above. A maximum pin measure-

[2] 0.0017 is 60% of total allowable errors (Table 2) when N equals zero.

[3] The factors E and F refer to the ratio of change of over-pin measurement to the change of circular tooth thickness, and is $\frac{\text{Cos } \phi}{\text{Sin } \phi_e}$ for the external serration and $\frac{\text{Cos } \phi}{\text{Sin } \phi_i}$ for the internal serration. (See Figs. 2 and 3)

ment may be used equal to the minimum pin measurement plus the machining tolerance times factor E.

20. **Allowable Errors**

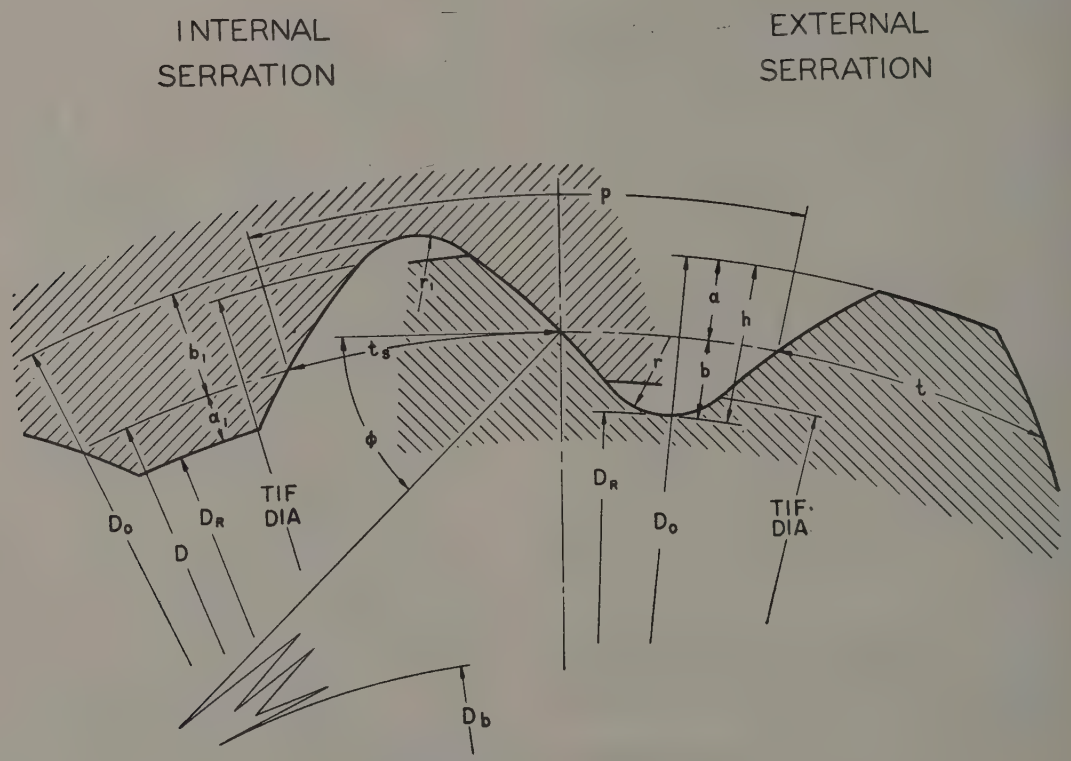
(a)—*Accumulated Pitch Error* (*Spacing*) is the greatest difference in any two teeth between the actual and theoretical tooth spacing on the same circle. Measurements are taken from one pitch point selected as reference to the corresponding points on all other teeth and will be affected by involute error and out of roundness.

(b)—*Profile Error* is the difference between the highest and lowest readings of a dial indicator moving along the true involute curve in the plane of rotation and having a finger contacting the active tooth profile.

(c)—*Lead Error* is a deviation of the teeth from the dimensional lead of serration per unit of face width. Lead error is usually measured by traversing a dial indicator along the tooth face normal to the pitch line and parallel to the axis of the serration.

(d)—*Out of Roundness* is the difference between the maximum and minimum measurements over or between pins.

(e)—*Application of Errors*. Experience has shown that not all



P = diametral pitch
p = circular pitch
a = addendum external
a_1 = addendum internal
b = dedendum external
b_1 = dedendum internal
h = total depth
t = circular tooth thickness
t_s = circular space width
M_e = measurement over pins, external serration
M_i = measurement between pins, internal serration
ϕ = pressure angle at pitch line
N = number of teeth
D = pitch diameter
D_b = base-circle diameter
D_o = major diameter
D_R = minor diameter
d = measuring-pin diameter
TIF = diameter at junction of involute form with fillet
r and r_1 = approximate radius of fillet

Fig. 1—Tooth Nomenclature

of the possible extremes will occur at one time, so that instead of using the total of all errors, 60% has been adopted as a fair maximum for computing effective fits. (See Table 2 for application of errors to fits.)

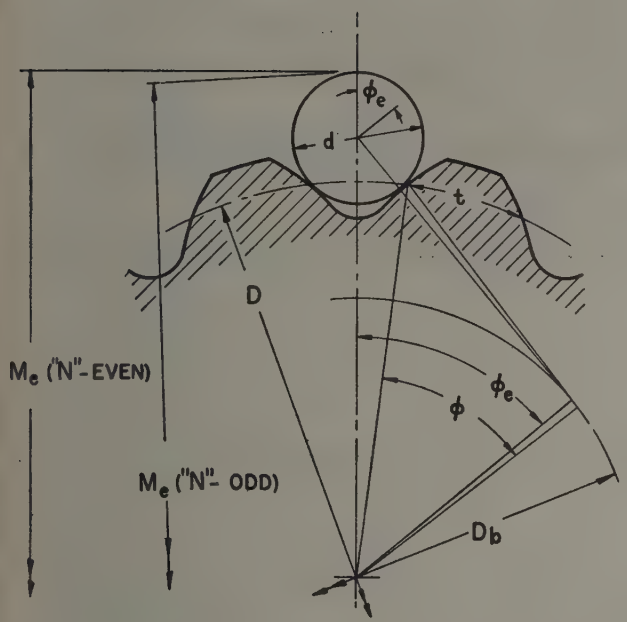
21. **Special Allowances**—The errors in Table 2 are based on Class 3 of American Standard for Gear Tolerances and Inspection, ASA B6.6-1946. If less accuracy can be permitted, use 133⅓% of the errors in Table 2, and if greater accuracy is required, use 66⅔% of those errors. In all cases, use 60% of the total for calculating effective fits.

Since internal serration is usually broached, 66⅔% of the table allowances may be used for mass production with the consent of the broach maker.

22. **Space-Tooth Thickness; Formulas**—When the three allowable errors of profile, pitch, and out-of-roundness effect on t are added, the result is a gradually increasing amount approximated by the formulas given below which incorporate 60% of the total amount, excepting lead. These formulas are used for calculating space width and tooth thickness in Tables 11 and 13.

DIAMETRAL PITCH	INTERNAL[a]	EXTERNAL[a]		
		Class A	Class B	Class C
10/20	Basic $+(0.072N+26)$	Basic $-(0.06N+37)$	Basic $-(0.06N+22)$	Basic $-(0.06N+2)$
16/32	Basic $+(0.048N+26)$	Basic $-(0.036N+37)$	Basic $-(0.036N+22)$	Basic $-(0.036N+2)$
24/48	Basic $+(0.036N+26)$	Basic $-(0.018N+32)$	Basic $-(0.018N+17)$	Basic $-(0.018N-3)$
32/64–128/256	Basic $+(0.024N+26)$	Basic $-(0.012N+32)$	Basic $-(0.012N+17)$	Basic $-(0.012N-3)$

[a] Result will be in ten thousandths of an inch.



ϕ = pressure angle at D, 45 deg

ϕ_e = pressure angle at pin center (deg)

d = pin diameter

D_b = base-circle diameter (D cos 45 deg)

t = circular tooth thickness

$$\text{Inv } \phi_e = \text{Inv } 45° + \frac{d}{D_b} + \frac{t}{D} - \frac{\pi}{N} \tag{1}$$

If N is even, use

$$M_e = D_b^* \sec \phi_e t^d, \quad \text{or} \quad \frac{D_b^*}{\cos \phi_e} + d \tag{2}$$

If N is odd, use

$$M_e = D_b^* \sec \phi_e \cos \frac{90°}{N} + d,$$

$$\text{or} \quad \frac{D_b^* \cos \frac{90°}{N}}{\cos \phi_e} + d \tag{3}$$

Example:

Standard dimensions for $N=20$, $P=10/20$, Class B fit, $d = 0.1920$
Basic tooth thickness $= 0.1771$
Allowable errors (Table 13) $= 0.0023$
Minimum tooth thickness $t = 0.1748$

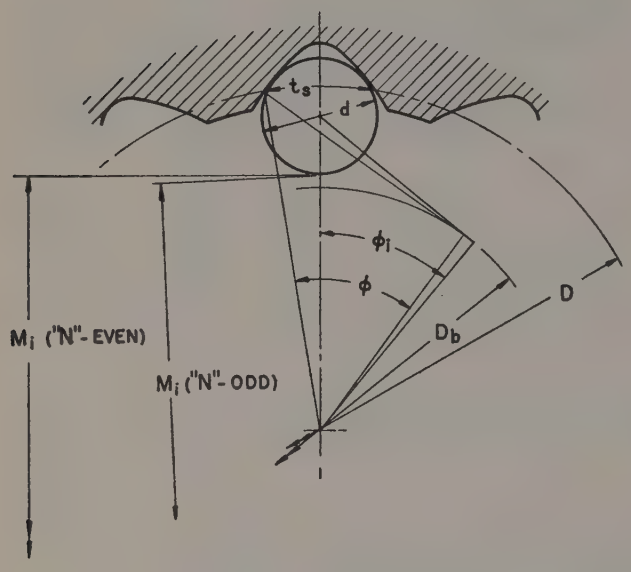
$$\text{Inv } \phi_e = 0.214602 + \frac{0.1920}{1.4142} + \frac{0.1748}{2.0000} - 0.157080 = 0.280688$$

$$\phi_e = 48.359307°$$

$$M_e = 1.4142 \sec 48.359307° + 0.1920 = 2.3203$$

* For all calculations, the base-circle diameter and the pitch diameter should be accurate to the sixth decimal place. To obtain this accuracy, divide the dimension for D_b in Table 3 by the diametral pitch P (numerator of fractional designation). To obtain D to the sixth decimal place, divide the pitch diameter from Table 4 or 5 by the diametral pitch used, as above, and multiply quotient by 10.

FIG. 2—FORMULAS FOR PIN MEASUREMENTS, EXTERNAL SERRATION



ϕ_i = pressure angle at pin center (deg)

t_s = circular space width, basic

d = pin diameter

$$\text{Inv } \phi_i = \text{Inv } 45° + \frac{t_s}{D} - \frac{d}{D_b} \tag{4}$$

If N is even, use

$$M_i = D_b^* \sec \phi_i - d, \quad \text{or} \quad \frac{D_b^*}{\cos \phi_i} - d \tag{5}$$

If N is odd, use

$$M_i = D_b^* \sec \phi_i \cos \frac{90°}{N} - \text{d},$$

$$\text{or} \quad \frac{D_b^* \cos \dfrac{90°}{N}}{\cos \phi_i} - d \tag{6}$$

Example:

Standard dimensions for $N=20$, $P=10/20$, internal serrations,	$d = 0.1920$
Basic space width	$= 0.1771$
Allowable errors (Table 11)	$= 0.0047$
Maximum space width	$t_s = 0.1798$

$$\text{Inv } \phi_i = 0.214602 + \frac{0.1798}{2.0000} - \frac{0.1920}{1.4142} = 0.168736$$

$$\phi_i = 42.096509°$$

$$M_i = 1.4142 \sec 42.096509° - 0.1920 = 1.7139$$

* For all calculations, the base-circle diameter and the pitch diameter should be accurate to the sixth decimal place. To obtain this accuracy, divide the dimension for D_b in Table 3 by the diametral pitch P (numerator of fractional designation). To obtain D to the sixth decimal place, divide the pitch diameter from Table 4 or 5 by the diametral pitch used, as above, and multiply quotient by 10.

FIG. 3—FORMULAS FOR PIN MEASUREMENTS, INTERNAL SERRATION

TABLE 1—*Basic Tooth Dimensions*

DIAMETRAL PITCH	EXTERNAL ADDENDUM, DEDENDUM	INTERNAL SERRATION		CIRCULAR PITCH	MINIMUM EFFECTIVE SPACE	MAXIMUM EFFECTIVE TOOTH THICKNESS			MEASURING PIN DIAMETER
		Addendum	Dedendum			Class of Fit			
P	$a = b$	a_1	b_1	p	t_s	A	B	C	d
1/2	0.5000	0.3000	0.7000	3.1416	1.7708	1.7703	1.7718	1.7738	1.9200
10/20	0.0500	0.0300	0.0700	0.3142	0.1771	0.1766	0.1781	0.1801	0.1920
16/32	0.0313	0.0188	0.0438	0.1963	0.1107	0.1102	0.1117	0.1137	0.1200
24/48	0.0208	0.0125	0.0292	0.1309	0.0738	0.0733	0.0748	0.0768	0.0800
32/64	0.0156	0.0094	0.0218	0.0982	0.0553	0.0548	0.0563	0.0583	0.0600
40/80	0.0125	0.0075	0.0175	0.0785	0.0443	0.0438	0.0453	0.0473	0.0480
48/96	0.0104	0.0063	0.0145	0.0654	0.0369	0.0364	0.0379	0.0399	0.0400
64/128	0.0078	0.0047	0.0109	0.0491	0.0277	0.0272	0.0287	0.0307	0.0300
80/160	0.0063	0.0038	0.0088	0.0393	0.0221	0.0216	0.0231	0.0251	0.0240
128/256	0.0039	0.0023	0.0055	0.0245	0.0138	0.0133	0.0148	0.0168	0.0150

TABLE 2—*Allowable Errors*[a]

DIAMETRAL PITCH	INVOLUTE PROFILE	ACCUMULATED PITCH ERROR BETWEEN ANY TWO TEETH	LEAD ERRORS					
			Length of serration					
			0 to 0.49	0.50 to 1.24	1.25 to 2.49	2.50 to 3.99	4.00 to 5.24	5.25 to 6.50
10/20	5	15	0	3	3	4	5	6
16/32	5	15	0	3	3	4	5	6
24/48	5	15	0	3	3	4	5	6
32/64 up	5	15	0	3	3	4	5	6

	OUT OF ROUNDNESS—INTERNAL																	MACHINING TOLERANCE
	Number of Teeth																	
	6	8	10	12	14	16	20	25	30	35	40	45	50	60	70	80	90	100	Internal
10/20	11	10	9	9	9	10	10	10	11	12	12	13	13	14	16	17	18	19	10
16/32	10	9	9	9	9	9	9	9	10	10	10	11	11	12	13	13	14	15	10
24/48	10	9	9	9	9	9	9	9	9	9	10	10	10	11	11	12	13	13	10
32/64 up	10	9	8	8	8	8	8	8	8	9	9	9	9	9	10	10	11	11	10

	OUT OF ROUNDNESS—EXTERNAL																	
	Number of Teeth																	
	6	8	10	12	14	16	20	25	30	35	40	45	50	60	70	80	90	100	External
10/20	8	9	9	9	10	10	10	11	12	12	13	13	14	15	16	17	18	19	15
16/32	8	8	9	9	9	9	10	10	10	11	11	11	12	12	13	14	14	15	15
24/48	8	8	8	9	9	9	9	9	10	10	10	10	10	11	11	11	12	12	10
32/64 up	8	8	8	8	8	8	9	9	9	9	9	10	10	10	10	10	11	11	10

[a] All table figures are ten thousandths of inch. Add the profile error, accumulated pitch error, and the out of roundness divided by F or E. If serration is longer than its pitch diameter, a lead error may be added.

TABLE 3—*Basic Data*

1/2 DP			ALL DIAMETRAL PITCHES			
Int and ext		Ext	Int and ext		Int	Ext
N	D_b	Meas over pins	$\cos\frac{90°}{N}$	$\frac{d}{D_b}$	$\frac{t_s}{D}$	$\frac{\pi}{N}$
1	2	3	4	5	6	7
6	4.242641	9.1631		0.452548	0.295133	0.523599
7	4.949747	9.9666	0.974928	0.387899	0.252971	0.448799
8	5.656854	11.1820		0.339411	0.221350	0.392699
9	6.363961	12.0330	0.984808	0.301699	0.196756	0.349066
10	7.071068	13.1949		0.271529	0.177080	0.314159
11	7.778175	14.0749	0.989821	0.246845	0.160982	0.285599
12	8.485281	15.2042		0.226274	0.147567	0.261799
13	9.192388	16.1039	0.992709	0.208868	0.136215	0.241661
14	9.899495	17.2114		0.193949	0.126486	0.224399
15	10.606602	18.1251	0.994522	0.181019	0.118053	0.209440
16	11.313708	19.2170		0.169706	0.110675	0.196350
17	12.020815	20.1413	0.995734	0.159723	0.104165	0.184800
18	12.727922	21.2215		0.150849	0.098378	0.174533
19	13.435029	22.1541	0.996584	0.142910	0.093200	0.165347
20	14.142136	23.2253		0.135764	0.088540	0.157080
21	14.849242	24.1645	0.997204	0.129300	0.084324	0.149600
22	15.556349	25.2284		0.123422	0.080491	0.142800
23	16.263456	26.1731	0.997669	0.118056	0.076991	0.136591
24	16.970563	27.2311		0.113137	0.073783	0.130900
25	17.677670	28.1804	0.998027	0.108612	0.070832	0.125664
26	18.384776	29.2334		0.104434	0.068108	0.120830
27	19.091883	30.1865	0.998308	0.100566	0.065585	0.116355
28	19.798990	31.2354		0.096975	0.063243	0.112200
29	20.506097	32.1918	0.998533	0.093631	0.061062	0.108331
30	21.213203	33.2372		0.090510	0.059027	0.104720
31	21.920310	34.1965	0.998717	0.087590	0.057123	0.101342
32	22.627417	35.2387		0.084853	0.055338	0.098175
33	23.334524	36.2006	0.998867	0.082282	0.053661	0.095200
34	24.041631	37.2401		0.079861	0.052082	0.092400
35	24.748737	38.2042	0.998993	0.077580	0.050594	0.089760
36	25.455844	39.2414		0.075425	0.049189	0.087266
37	26.162951	40.2074	0.999099	0.073386	0.047859	0.084908
38	26.870058	41.2425		0.071455	0.046600	0.082673
39	27.577164	42.2103	0.999189	0.069623	0.045405	0.080554
40	28.284271	43.2435		0.067882	0.044270	0.078540
41	28.991378	44.2129	0.999266	0.066227	0.043190	0.076624
42	29.698485	45.2445		0.064650	0.042162	0.074800
43	30.405592	46.2153	0.999333	0.063146	0.041181	0.073060
44	31.112698	47.2453		0.061711	0.040245	0.071400
45	31.819805	48.2175	0.999391	0.060340	0.039351	0.069813
46	32.526912	49.2461		0.059028	0.038496	0.068295
47	33.234019	50.2195	0.999442	0.057772	0.037677	0.066842
48	33.941125	51.2468		0.056569	0.036892	0.065450
49	34.648232	52.2213	0.999486	0.055414	0.036139	0.064114
50	35.355339	53.2474		0.054306	0.035416	0.062832

1/2 DP			ALL DIAMETRAL PITCHES			
Int and ext		Ext	Int and ext		Int	Ext
N	D_b	Meas over pins	$\cos\frac{90°}{N}$	$\frac{d}{D_b}$	$\frac{t_s}{D}$	$\frac{\pi}{N}$
1	2	3	4	5	6	7
51	36.062446	54.2230	0.999526	0.053241	0.034722	0.061600
52	36.769553	55.2481		0.052217	0.034054	0.060415
53	37.476659	56.2245	0.999561	0.051232	0.033411	0.059275
54	38.183766	57.2487		0.050283	0.032793	0.058178
55	38.890873	58.2260	0.999592	0.049369	0.032196	0.057120
56	39.597980	59.2492		0.048487	0.031621	0.056100
57	40.305087	60.2273	0.999620	0.047637	0.031067	0.055116
58	41.012193	61.2497		0.046815	0.030531	0.054165
59	41.719300	62.2286	0.999646	0.046022	0.030014	0.053247
60	42.426407	63.2502		0.045255	0.029513	0.052360
61	43.133514	64.2297	0.999668	0.044513	0.029030	0.051502
62	43.840620	65.2506		0.043795	0.028561	0.050671
63	44.547727	66.2308	0.999689	0.043100	0.028108	0.049867
64	45.254834	67.2510		0.042426	0.027669	0.049087
65	45.961941	68.2319	0.999708	0.041774	0.027243	0.048332
66	46.669048	69.2514		0.041141	0.026830	0.047600
67	47.376154	70.2328	0.999725	0.040527	0.026430	0.046889
68	48.083261	71.2518		0.039931	0.026041	0.046200
69	48.790368	72.2337	0.999741	0.039352	0.025664	0.045530
70	49.497475	73.2521		0.038790	0.025297	0.044880
71	50.204581	74.2346	0.999755	0.038244	0.024941	0.044248
72	50.911688	75.2525		0.037712	0.024594	0.043633
73	51.618795	76.2354	0.999768	0.037196	0.024258	0.043036
74	52.325902	77.2528		0.036693	0.023930	0.042454
75	53.033009	78.2362	0.999781	0.036204	0.023611	0.041888
76	53.740115	79.2531		0.035728	0.023300	0.041337
77	54.447222	80.2369	0.999792	0.035264	0.022997	0.040800
78	55.154329	81.2533		0.034811	0.022703	0.040277
79	55.861436	82.2376	0.999802	0.034371	0.022415	0.039767
80	56.568542	83.2536		0.033941	0.022135	0.039270
81	57.275649	84.2383	0.999812	0.033522	0.021862	0.038785
82	57.982756	85.2539		0.033113	0.021595	0.038312
83	58.689863	86.2389	0.999821	0.032714	0.021335	0.037851
84	59.396970	87.2541		0.032325	0.021081	0.037400
85	60.104076	88.2395	0.999829	0.031945	0.020833	0.036960
86	60.811183	89.2544		0.031573	0.020591	0.036530
87	61.518290	90.2401	0.999837	0.031210	0.020354	0.036110
88	62.225397	91.2546		0.030856	0.020123	0.035700
89	62.932504	92.2406	0.999844	0.030509	0.019897	0.035299
90	63.639610	93.2548		0.030170	0.019676	0.034907
91	64.346717	94.2411	0.999851	0.029838	0.019459	0.034523
92	65.053824	95.2550		0.029514	0.019248	0.034148
93	65.760931	96.2416	0.999857	0.029197	0.019041	0.033781
94	66.468037	97.2552		0.028886	0.018838	0.033421
95	67.175144	98.2421	0.999863	0.028582	0.018640	0.033069
96	67.882251	99.2554		0.028284	0.018446	0.032725
97	68.589358	100.2426	0.999869	0.027993	0.018256	0.032388
98	69.296465	101.2556		0.027707	0.018069	0.032057
99	70.003571	102.2430	0.999874	0.027427	0.017887	0.031733
100	70.710678	103.2557		0.027153	0.017708	0.031416

Constants

π = 3.141593
cos 45 deg = 0.707107
Inv 45 deg = 0.214602

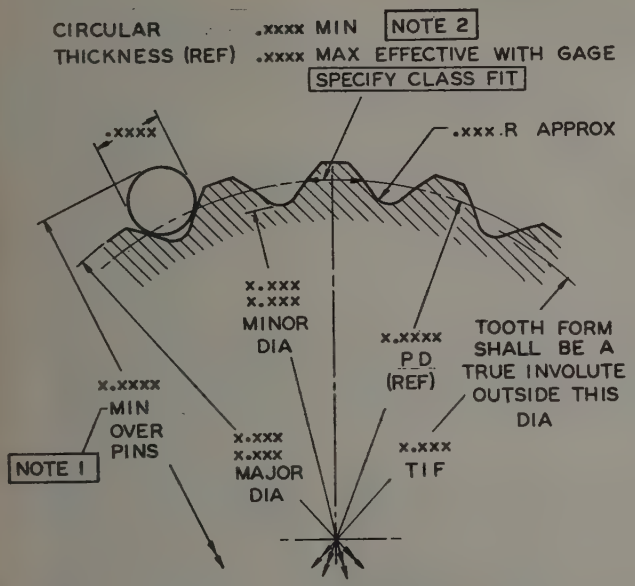


Fig. 4—Dimensioning Drawing, External Serration

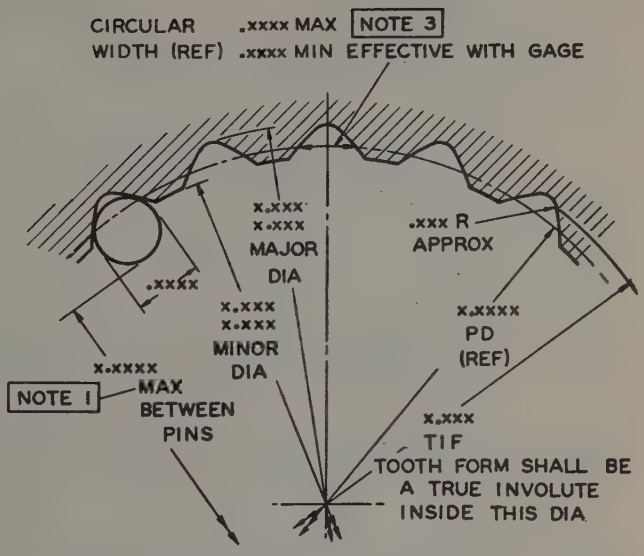


Fig. 5—Dimensioning Drawing, Internal Serration

Notes for Figs. 4 and 5: (Boxed notes are for instruction only)

Note 1—See Section 19 and Table 2 for machining tolerances.

Note 2—Obtain tooth thickness from Tables 1 and 13.

Note 3—Obtain space width from Tables 1 and 11.

Note 4—The data below should be given for both internal and external serrations. See Table 2.

Number of teeth	xx	Maximum out of roundness	.xxxx
Diametral pitch	xx/xx	Maximum cumulative pitch error (any two teeth)	.xxxx
Pressure angle	xx°	Maximum involute profile error	.xxxx
Base-circle diameter	x.xxxx	Maximum lead error	.xxxx

TABLE 4—*10/20 Diametral Pitch*[a]

10/20 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.3142 Circular Tooth Thickness, 0.1771	Addendum, External, 0.0500 Addendum, Internal, 0.0300
Cutting-tool radius, 0.045	Measuring-pin diameter, internal and external, 0.1920	

	INT AND EXT		INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance⟶			+0.0100 −0.0000	+0.0100 −0.0000		Max	+0.0000 −0.0100	+0.0000 −0.0100		Min	Min	Min	
6	0.6000	0.4243	0.7400	0.5400	0.7100	0.3044	0.7000	0.5000	0.5300	0.9131	0.9144	0.9161	0.872
7	0.7000	0.4950	0.8400	0.6400	0.8100	0.3923	0.8000	0.6000	0.6300	0.9934	0.9948	0.9965	0.884
8	0.8000	0.5657	0.9400	0.7400	0.9100	0.5088	0.9000	0.7000	0.7300	1.1149	1.1162	1.1180	0.893
9	0.9000	0.6364	1.0400	0.8400	1.0100	0.5978	1.0000	0.8000	0.8300	1.2000	1.2013	1.2031	0.901
10	1.0000	0.7071	1.1400	0.9400	1.1100	0.7108	1.1000	0.9000	0.9300	1.3161	1.3174	1.3192	0.908
11	1.1000	0.7778	1.2400	1.0400	1.2100	0.8012	1.2000	1.0000	1.0300	1.4040	1.4054	1.4072	0.914
12	1.2000	0.8485	1.3400	1.1400	1.3100	0.9120	1.3000	1.1000	1.1300	1.5169	1.5183	1.5201	0.919
13	1.3000	0.9192	1.4400	1.2400	1.4100	1.0035	1.4000	1.2000	1.2300	1.6069	1.6083	1.6101	0.924
14	1.4000	0.9900	1.5400	1.3400	1.5100	1.1126	1.5000	1.3000	1.3300	1.7176	1.7190	1.7208	0.928
15	1.5000	1.0607	1.6400	1.4400	1.6100	1.2053	1.6000	1.4000	1.4300	1.8090	1.8104	1.8122	0.931
16	1.6000	1.1314	1.7400	1.5400	1.7100	1.3132	1.7000	1.5000	1.5300	1.9182	1.9196	1.9214	0.935
17	1.7000	1.2021	1.8400	1.6400	1.8100	1.4066	1.8000	1.6000	1.6300	2.0105	2.0119	2.0138	0.938
18	1.8000	1.2728	1.9400	1.7400	1.9100	1.5136	1.9000	1.7000	1.7300	2.1186	2.1200	2.1219	0.941
19	1.9000	1.3435	2.0400	1.8400	2.0100	1.6076	2.0000	1.8000	1.8300	2.2118	2.2132	2.2151	0.943
20	2.0000	1.4142	2.1400	1.9400	2.1100	1.7139	2.1000	1.9000	1.9300	2.3189	2.3203	2.3222	0.945
21	2.1000	1.4849	2.2400	2.0400	2.2100	1.8086	2.2000	2.0000	2.0300	2.4129	2.4143	2.4162	0.948
22	2.2000	1.5556	2.3400	2.1400	2.3100	1.9143	2.3000	2.1000	2.1300	2.5192	2.5206	2.5225	0.950
23	2.3000	1.6263	2.4400	2.2400	2.4100	2.0092	2.4000	2.2000	2.2300	2.6137	2.6151	2.6170	0.951
24	2.4000	1.6971	2.5400	2.3400	2.5100	2.1144	2.5000	2.3000	2.3300	2.7195	2.7209	2.7228	0.953
25	2.5000	1.7678	2.6400	2.4400	2.6100	2.2098	2.6000	2.4000	2.4300	2.8143	2.8157	2.8176	0.955
26	2.6000	1.8385	2.7400	2.5400	2.7100	2.3146	2.7000	2.5000	2.5300	2.9195	2.9210	2.9229	0.956
27	2.7000	1.9092	2.8400	2.6400	2.8100	2.4102	2.8000	2.6000	2.6300	3.0150	3.0164	3.0183	0.958
28	2.8000	1.9799	2.9400	2.7400	2.9100	2.5147	2.9000	2.7000	2.7300	3.1198	3.1212	3.1231	0.959
29	2.9000	2.0506	3.0400	2.8400	3.0100	2.6107	3.0000	2.8000	2.8300	3.2155	3.2169	3.2188	0.960
30	3.0000	2.1213	3.1400	2.9400	3.1100	2.7148	3.1000	2.9000	2.9300	3.3200	3.3214	3.3233	0.961
31	3.1000	2.1920	3.2400	3.0400	3.2100	2.8110	3.2000	3.0000	3.0300	3.4159	3.4174	3.4193	0.962
32	3.2000	2.2627	3.3400	3.1400	3.3100	2.9150	3.3000	3.1000	3.1300	3.5201	3.5216	3.5235	0.963
33	3.3000	2.3335	3.4400	3.2400	3.4100	3.0114	3.4000	3.2000	3.2300	3.6163	3.6178	3.6197	0.964
34	3.4000	2.4042	3.5400	3.3400	3.5100	3.1151	3.5000	3.3000	3.3300	3.7202	3.7217	3.7236	0.965
35	3.5000	2.4749	3.6400	3.4400	3.6100	3.2118	3.6000	3.4000	3.4300	3.8166	3.8181	3.8200	0.966
36	3.6000	2.5456	3.7400	3.5400	3.7100	3.3152	3.7000	3.5000	3.5300	3.9203	3.9218	3.9237	0.967
37	3.7000	2.6163	3.8400	3.6400	3.8100	3.4120	3.8000	3.6000	3.6300	4.0170	4.0185	4.0204	0.968
38	3.8000	2.6870	3.9400	3.7400	3.9100	3.5153	3.9000	3.7000	3.7300	4.1205	4.1220	4.1239	0.968
39	3.9000	2.7577	4.0400	3.8400	4.0100	3.6123	4.0000	3.8000	3.8300	4.2172	4.2187	4.2206	0.969
40	4.0000	2.8284	4.1400	3.9400	4.1100	3.7154	4.1000	3.9000	3.9300	4.3206	4.3221	4.3240	0.970
41	4.1000	2.8991	4.2400	4.0400	4.2100	3.8125	4.2000	4.0000	4.0300	4.4175	4.4190	4.4209	0.971
42	4.2000	2.9698	4.3400	4.1400	4.3100	3.9154	4.3000	4.1000	4.1300	4.5205	4.5220	4.5239	0.971
43	4.3000	3.0406	4.4400	4.2400	4.4100	4.0127	4.4000	4.2000	4.2300	4.6176	4.6191	4.6210	0.972
44	4.4000	3.1113	4.5400	4.3400	4.5100	4.1155	4.5000	4.3000	4.3300	4.7206	4.7221	4.7240	0.972
45	4.5000	3.1820	4.6400	4.4400	4.6100	4.2128	4.6000	4.4000	4.4300	4.8179	4.8194	4.8213	0.973
46	4.6000	3.2527	4.7400	4.5400	4:7100	4.3155	4.7000	4.5000	4.5300	4.9207	4.9222	4.9241	0.973
47	4.7000	3.3234	4.8400	4.6400	4.8100	4.4130	4.8000	4.6000	4.6300	5.0181	5.0196	5.0215	0.974
48	4.8000	3.3941	4.9400	4.7400	4.9100	4.5156	4.9000	4.7000	4.7300	5.1208	5.1223	5.1242	0.974
49	4.9000	3.4648	5.0400	4.8400	5.0100	4.6132	5.0000	4.8000	4.8300	5.2182	5.2197	5.2216	0.975
50	5.0000	3.5355	5.1400	4.9400	5.1100	4.7157	5.1000	4.9000	4.9300	5.3209	5.3224	5.3243	0.975

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.

(*Continued on next page.*)

TABLE 4—*10/20 Diametral Pitch (Concluded)*

10/20 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.3142 Circular Tooth Thickness, 0.1771	Addendum, External, 0.0500 Addendum, Internal, 0.0300
Cutting-tool radius, 0.045	Measuring-pin diameter, internal and external, 0.1920	

INT AND EXT			INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance⟶			+0.0100 −0.0000	+0.0100 −0.0000		Max	+0.0000 −0.0100	+0.0000 −0.0100		Min	Min	Min	
51	5.1000	3.6062	5.2400	5.0400	5.2100	4.8134	5.2000	5.0000	5.0300	5.4184	5.4199	5.4218	0.976
52	5.2000	3.6770	5.3400	5.1400	5.3100	4.9158	5.3000	5.1000	5.1300	5.5209	5.5224	5.5243	0.976
53	5.3000	3.7477	5.4400	5.2400	5.4100	5.0135	5.4000	5.2000	5.2300	5.6186	5.6201	5.6220	0.977
54	5.4000	3.8184	5.5400	5.3400	5.5100	5.1158	5.5000	5.3000	5.3300	5.7210	5.7225	5.7244	0.977
55	5.5000	3.8891	5.6400	5.4400	5.6100	5.2136	5.6000	5.4000	5.4300	5.8187	5.8202	5.8221	0.977
56	5.6000	3.9598	5.7400	5.5400	5.7100	5.3158	5.7000	5.5000	5.5300	5.9210	5.9225	5.9244	0.978
57	5.7000	4.0305	5.8400	5.6400	5.8100	5.4137	5.8000	5.6000	5.6300	6.0188	6.0203	6.0222	0.978
58	5.8000	4.1012	5.9400	5.7400	5.9100	5.5159	5.9000	5.7000	5.7300	6.1211	6.1226	6.1245	0.979
59	5.9000	4.1719	6.0400	5.8400	6.0100	5.6138	6.0000	5.8000	5.8300	6.2189	6.2204	6.2223	0.979
60	6.0000	4.2426	6.1400	5.9400	6.1100	5.7159	6.1000	5.9000	5.9300	6.3210	6.3225	6.3244	0.979
61	6.1000	4.3134	6.2400	6.0400	6.2100	5.8139	6.2000	6.0000	6.0300	6.4190	6.4205	6.4224	0.980
62	6.2000	4.3841	6.3400	6.1400	6.3100	5.9159	6.3000	6.1000	6.1300	6.5211	6.5226	6.5245	0.980
63	6.3000	4.4548	6.4400	6.2400	6.4100	6.0140	6.4000	6.2000	6.2300	6.6191	6.6206	6.6225	0.980
64	6.4000	4.5255	6.5400	6.3400	6.5100	6.1159	6.5000	6.3000	6.3300	6.7211	6.7226	6.7245	0.980
65	6.5000	4.5962	6.6400	6.4400	6.6100	6.2141	6.6000	6.4000	6.4300	6.8192	6.8207	6.8226	0.981
66	6.6000	4.6669	6.7400	6.5400	6.7100	6.3160	6.7000	6.5000	6.5300	6.9211	6.9226	6.9245	0.981
67	6.7000	4.7376	6.8400	6.6400	6.8100	6.4142	6.8000	6.6000	6.6300	7.0193	7.0208	7.0227	0.981
68	6.8000	4.8083	6.9400	6.7400	6.9100	6.5160	6.9000	6.7000	6.7300	7.1212	7.1227	7.1246	0.982
69	6.9000	4.8790	7.0400	6.8400	7.0100	6.6142	7.0000	6.8000	6.8300	7.2194	7.2209	7.2228	0.982
70	7.0000	4.9497	7.1400	6.9400	7.1100	6.7160	7.1000	6.9000	6.9300	7.3212	7.3226	7.3246	0.982
71	7.1000	5.0205	7.2400	7.0400	7.2100	6.8143	7.2000	7.0000	7.0300	7.4195	7.4209	7.4229	0.982
72	7.2000	5.0912	7.3400	7.1400	7.3100	6.9160	7.3000	7.1000	7.1300	7.5213	7.5227	7.5247	0.982
73	7.3000	5.1619	7.4400	7.2400	7.4100	7.0144	7.4000	7.2000	7.2300	7.6195	7.6209	7.6229	0.983
74	7.4000	5.2326	7.5400	7.3400	7.5100	7.1160	7.5000	7.3000	7.3300	7.7213	7.7227	7.7247	0.983
75	7.5000	5.3033	7.6400	7.4400	7.6100	7.2144	7.6000	7.4000	7.4300	7.8195	7.8209	7.8229	0.983
76	7.6000	5.3740	7.7400	7.5400	7.7100	7.3161	7.7000	7.5000	7.5300	7.9212	7.9226	7.9246	0.983
77	7.7000	5.4447	7.8400	7.6400	7.8100	7.4146	7.8000	7.6000	7.6300	8.0196	8.0210	8.0230	0.984
78	7.8000	5.5154	7.9400	7.7400	7.9100	7.5162	7.9000	7.7000	7.7300	8.1212	8.1226	8.1246	0.984
79	7.9000	5.5861	8.0400	7.8400	8.0100	7.6146	8.0000	7.8000	7.8300	8.2197	8.2211	8.2231	0.984
80	8.0000	5.6569	8.1400	7.9400	8.1100	7.7162	8.1000	7.9000	7.9300	8.3213	8.3227	8.3247	0.984
81	8.1000	5.7276	8.2400	8.0400	8.2100	7.8147	8.2000	8.0000	8.0300	8.4197	8.4211	8.4231	0.984
82	8.2000	5.7983	8.3400	8.1400	8.3100	7.9162	8.3000	8.1000	8.1300	8.5213	8.5227	8.5247	0.985
83	8.3000	5.8690	8.4400	8.2400	8.4100	8.0147	8.4000	8.2000	8.2300	8.6198	8.6212	8.6232	0.985
84	8.4000	5.9397	8.5400	8.3400	8.5100	8.1162	8.5000	8.3000	8.3300	8.7213	8.7227	8.7247	0.985
85	8.5000	6.0104	8.6400	8.4400	8.6100	8.2148	8.6000	8.4000	8.4300	8.8199	8.8213	8.8233	0.985
86	8.6000	6.0811	8.7400	8.5400	8.7100	8.3162	8.7000	8.5000	8.5300	8.9213	8.9227	8.9247	0.985
87	8.7000	6.1518	8.8400	8.6400	8.8100	8.4148	8.8000	8.6000	8.6300	9.0199	9.0213	9.0233	0.985
88	8.8000	6.2225	8.9400	8.7400	8.9100	8.5162	8.9000	8.7000	8.7300	9.1214	9.1228	9.1248	0.985
89	8.9000	6.2933	9.0400	8.8400	9.0100	8.6149	9.0000	8.8000	8.8300	9.2200	9.2214	9.2234	0.986
90	9.0000	6.3640	9.1400	8.9400	9.1100	8.7162	9.1000	8.9000	8.9300	9.3214	9.3228	9.3248	0.986
91	9.1000	6.4347	9.2400	9.0400	9.2100	8.8150	9.2000	9.0000	9.0300	9.4200	9.4214	9.4234	0.986
92	9.2000	6.5054	9.3400	9.1400	9.3100	8.9164	9.3000	9.1000	9.1300	9.5213	9.5227	9.5247	0.986
93	9.3000	6.5761	9.4400	9.2400	9.4100	9.0151	9.4000	9.2000	9.2300	9.6200	9.6214	9.6234	0.986
94	9.4000	6.6468	9.5400	9.3400	9.5100	9.1164	9.5000	9.3000	9.3300	9.7213	9.7227	9.7247	0.986
95	9.5000	6.7175	9.6400	9.4400	9.6100	9.2151	9.6000	9.4000	9.4300	9.8200	9.8214	9.8234	0.986
96	9.6000	6.7882	9.7400	9.5400	9.7100	9.3164	9.7000	9.5000	9.5300	9.9213	9.9227	9.9247	0.987
97	9.7000	6.8589	9.8400	9.6400	9.8100	9.4151	9.8000	9.6000	9.6300	10.0201	10.0215	10.0235	0.987
98	9.8000	6.9296	9.9400	9.7400	9.9100	9.5164	9.9000	9.7000	9.7300	10.1214	10.1228	10.1248	0.987
99	9.9000	7.0004	10.0400	9.8400	10.0100	9.6152	10.0000	9.8000	9.8300	10.2201	10.2215	10.2235	0.987
100	10.0000	7.0711	10.1400	9.9400	10.1100	9.7164	10.1000	9.9000	9.9300	10.3214	10.3228	10.3248	0.987

TABLE 5—*16/32 Diametral Pitch*[a]

16/32 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.1963 Circular Tooth Thickness, 0.1107	Addendum, External, 0.0313 Addendum, Internal, 0.0188
Cutting-tool radius, 0.028	Measuring-pin diameter, internal and external, 0.1200	

INT AND EXT			INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance→			+0.0060 −0.0000	+0.0060 −0.0000		Max	+0.0000 −0.0060	+0.0000 −0.0060		Min	Min	Min	
6	0.3750	0.2652	0.4625	0.3375	0.4438	0.1916	0.4375	0.3125	0.3313	0.5695	0.5708	0.5725	0.872
7	0.4375	0.3094	0.5250	0.4000	0.5063	0.2462	0.5000	0.3750	0.3938	0.6196	0.6210	0.6227	0.884
8	0.5000	0.3536	0.5875	0.4625	0.5688	0.3191	0.5625	0.4375	0.4563	0.6956	0.6969	0.6987	0.893
9	0.5625	0.3977	0.6500	0.5250	0.6313	0.3747	0.6250	0.5000	0.5188	0.7488	0.7501	0.7519	0.901
10	0.6250	0.4419	0.7125	0.5875	0.6938	0.4453	0.6875	0.5625	0.5813	0.8213	0.8227	0.8245	0.908
11	0.6875	0.4861	0.7750	0.6500	0.7563	0.5019	0.7500	0.6250	0.6438	0.8763	0.8777	0.8795	0.914
12	0.7500	0.5303	0.8375	0.7125	0.8188	0.5710	0.8125	0.6875	0.7063	0.9469	0.9483	0.9501	0.919
13	0.8125	0.5745	0.9000	0.7750	0.8813	0.6283	0.8750	0.7500	0.7688	1.0031	1.0045	1.0063	0.924
14	0.8750	0.6187	0.9625	0.8375	0.9438	0.6965	0.9375	0.8125	0.8313	1.0722	1.0736	1.0754	0.928
15	0.9375	0.6629	1.0250	0.9000	1.0063	0.7544	1.0000	0.8750	0.8938	1.1293	1.1307	1.1325	0.931
16	1.0000	0.7071	1.0875	0.9625	1.0688	0.8218	1.0625	0.9375	0.9563	1.1976	1.1990	1.2008	0.935
17	1.0625	0.7513	1.1500	1.0250	1.1313	0.8802	1.1250	1.0000	1.0188	1.2552	1.2566	1.2585	0.938
18	1.1250	0.7955	1.2125	1.0875	1.1938	0.9471	1.1875	1.0625	1.0813	1.3227	1.3241	1.3260	0.941
19	1.1875	0.8397	1.2750	1.1500	1.2563	1.0059	1.2500	1.1250	1.1438	1.3810	1.3824	1.3843	0.943
20	1.2500	0.8839	1.3375	1.2125	1.3188	1.0723	1.3125	1.1875	1.2063	1.4480	1.4494	1.4513	0.945
21	1.3125	0.9281	1.4000	1.2750	1.3813	1.1314	1.3750	1.2500	1.2688	1.5067	1.5081	1.5100	0.948
22	1.3750	0.9723	1.4625	1.3375	1.4438	1.1975	1.4375	1.3125	1.3313	1.5732	1.5746	1.5765	0.950
23	1.4375	1.0165	1.5250	1.4000	1.5063	1.2567	1.5000	1.3750	1.3938	1.6322	1.6336	1.6355	0.951
24	1.5000	1.0607	1.5875	1.4625	1.5688	1.3225	1.5625	1.4375	1.4563	1.6983	1.6997	1.7016	0.953
25	1.5625	1.1049	1.6500	1.5250	1.6313	1.3821	1.6250	1.5000	1.5188	1.7577	1.7591	1.7610	0.955
26	1.6250	1.1490	1.7125	1.5875	1.6938	1.4476	1.6875	1.5625	1.5813	1.8235	1.8249	1.8268	0.956
27	1.6875	1.1932	1.7750	1.6500	1.7563	1.5074	1.7500	1.6250	1.6438	1.8830	1.8844	1.8863	0.958
28	1.7500	1.2374	1.8375	1.7125	1.8188	1.5727	1.8125	1.6875	1.7063	1.9486	1.9500	1.9519	0.959
29	1.8125	1.2816	1.9000	1.7750	1.8813	1.6226	1.8750	1.7500	1.7688	2.0083	2.0097	2.0116	0.960
30	1.8750	1.3258	1.9625	1.8375	1.9438	1.6978	1.9375	1.8125	1.8313	2.0736	2.0751	2.0770	0.961
31	1.9375	1.3700	2.0250	1.9000	2.0063	1.7579	2.0000	1.8750	1.8938	2.1336	2.1351	2.1370	0.962
32	2.0000	1.4142	2.0875	1.9625	2.0688	1.8229	2.0625	1.9375	1.9563	2.1987	2.2002	2.2021	0.963
33	2.0625	1.4584	2.1500	2.0250	2.1313	1.8832	2.1250	2.0000	2.0188	2.2588	2.2603	2.2622	0.964
34	2.1250	1.5026	2.2125	2.0875	2.1938	1.9480	2.1875	2.0625	2.0813	2.3238	2.3253	2.3272	0.965
35	2.1875	1.5468	2.2750	2.1500	2.2563	2.0084	2.2500	2.1250	2.1438	2.3841	2.3856	2.3875	0.966
36	2.2500	1.5910	2.3375	2.2125	2.3188	2.0730	2.3125	2.1875	2.2063	2.4489	2.4504	2.4523	0.967
37	2.3125	1.6352	2.4000	2.2750	2.3813	2.1335	2.3750	2.2500	2.2688	2.5092	2.5107	2.5126	0.968
38	2.3750	1.6794	2.4625	2.3375	2.4438	2.1981	2.4375	2.3125	2.3313	2.5739	2.5754	2.5773	0.968
39	2.4375	1.7236	2.5250	2.4000	2.5063	2.2587	2.5000	2.3750	2.3938	2.6344	2.6359	2.6378	0.969
40	2.5000	1.7678	2.5875	2.4625	2.5688	2.3231	2.5625	2.4375	2.4563	2.6990	2.7005	2.7024	0.970
41	2.5625	1.8120	2.6500	2.5250	2.6313	2.3838	2.6250	2.5000	2.5188	2.7596	2.7611	2.7630	0.971
42	2.6250	1.8562	2.7125	2.5875	2.6938	2.4482	2.6875	2.5625	2.5813	2.8239	2.8254	2.8273	0.971
43	2.6875	1.9003	2.7750	2.6500	2.7563	2.5089	2.7500	2.6250	2.6438	2.8846	2.8861	2.8880	0.972
44	2.7500	1.9445	2.8375	2.7125	2.8188	2.5732	2.8125	2.6875	2.7063	2.9490	2.9505	2.9524	0.972
45	2.8125	1.9887	2.9000	2.7750	2.8813	2.6340	2.8750	2.7500	2.7688	3.0098	3.0113	3.0132	0.973
46	2.8750	2.0329	2.9625	2.8375	2.9438	2.6982	2.9375	2.8125	2.8313	3.0741	3.0756	3.0775	0.973
47	2.9375	2.0771	3.0250	2.9000	3.0063	2.7591	3.0000	2.8750	2.8938	3.1349	3.1364	3.1383	0.974
48	3.0000	2.1213	3.0875	2.9625	3.0688	2.8233	3.0625	2.9375	2.9563	3.1991	3.2006	3.2025	0.974
49	3.0625	2.1655	3.1500	3.0250	3.1313	2.8842	3.1250	3.0000	3.0188	3.2600	3.2615	3.2634	0.975
50	3.1250	2.2097	3.2125	3.0875	3.1938	2.9483	3.1875	3.0625	3.0813	3.3241	3.3256	3.3275	0.976

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.

(Continued on next page.)

TABLE 5—*16/32 Diametral Pitch (Concluded)*

16/32 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.1963 Circular Tooth Thickness, 0.1107	Addendum, External, 0.0313 Addendum, Internal, 0.0188
Cutting-tool radius, 0.028	Measuring-pin diameter, internal and external, 0.1200	

INT AND EXT			INTERNAL				EXTERNAL						
N	Pitch diam	Base circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance→			+0.0060 −0.0000	+0.0060 −0.0000		Max	+0.0000 −0.0060	+0.0000 −0.0060		Min	Min	Min	
51	3.1875	2.2539	3.2750	3.1500	3.2563	3.0093	3.2500	3.1250	3.1438	3.3851	3.3866	3.3885	0.976
52	3.2500	2.2981	3.3375	3.2125	3.3188	3.0733	3.3125	3.1875	3.2063	3.4492	3.4507	3.4526	0.976
53	3.3125	2.3423	3.4000	3.2750	3.3813	3.1344	3.3750	3.2500	3.2688	3.5102	3.5117	3.5136	0.977
54	3.3750	2.3865	3.4625	3.3375	3.4438	3.1983	3.4375	3.3125	3.3313	3.5742	3.5757	3.5776	0.977
55	3.4375	2.4307	3.5250	3.4000	3.5063	3.2595	3.5000	3.3750	3.3938	3.6353	3.6368	3.6387	0.977
56	3.5000	2.4749	3.5875	3.4625	3.5688	3.3235	3.5625	3.4375	3.4563	3.6993	3.7008	3.7027	0.978
57	3.5625	2.5191	3.6500	3.5250	3.6313	3.3846	3.6250	3.5000	3.5188	3.7604	3.7619	3.7638	0.978
58	3.6250	2.5633	3.7125	3.5875	3.6938	3.4484	3.6875	3.5625	3.5813	3.8243	3.8258	3.8277	0.979
59	3.6875	2.6075	3.7750	3.6500	3.7563	3.5096	3.7500	3.6250	3.6438	3.8855	3.8870	3.8889	0.979
60	3.7500	2.6517	3.8375	3.7125	3.8188	3.5734	3.8125	3.6875	3.7063	3.9493	3.9508	3.9527	0.979
61	3.8125	2.6958	3.9000	3.7750	3.8813	3.6346	3.8750	3.7500	3.7688	4.0106	4.0120	4.0140	0.980
62	3.8750	2.7400	3.9625	3.8375	3.9438	3.6984	3.9375	3.8125	3.8313	4.0744	4.0758	4.0778	0.980
63	3.9375	2.7842	4.0250	3.9000	4.0063	3.7597	4.0000	3.8750	3.8938	4.1356	4.1370	4.1390	0.980
64	4.0000	2.8284	4.0875	3.9625	4.0688	3.8234	4.0625	3.9375	3.9563	4.1994	4.2008	4.2028	0.980
65	4.0625	2.8726	4.1500	4.0250	4.1313	3.8848	4.1250	4.0000	4.0188	4.2607	4.2621	4.2641	0.981
66	4.1250	2.9168	4.2125	4.0875	4.1938	3.9484	4.1875	4.0625	4.0813	4.3244	4.3258	4.3278	0.981
67	4.1875	2.9610	4.2750	4.1500	4.2563	4.0098	4.2500	4.1250	4.1438	4.3858	4.3872	4.3892	0.981
68	4.2500	3.0052	4.3375	4.2125	4.3188	4.0734	4.3125	4.1875	4.2063	4.4494	4.4508	4.4528	0.982
69	4.3125	3.0494	4.4000	4.2750	4.3813	4.1349	4.3750	4.2500	4.2688	4.5108	4.5122	4.5142	0.982
70	4.3750	3.0936	4.4625	4.3375	4.4438	4.1985	4.4375	4.3125	4.3313	4.5744	4.5758	4.5778	0.982
71	4.4375	3.1378	4.5250	4.4000	4.5063	4.2599	4.5000	4.3750	4.3938	4.6358	4.6372	4.6392	0.982
72	4.5000	3.1820	4.5875	4.4625	4.5688	4.3235	4.5625	4.4375	4.4563	4.6994	4.7008	4.7028	0.982
73	4.5625	3.2262	4.6500	4.5250	4.6313	4.3850	4.6250	4.5000	4.5188	4.7608	4.7622	4.7642	0.983
74	4.6250	3.2704	4.7125	4.5875	4.6938	4.4486	4.6875	4.5625	4.5813	4.8244	4.8258	4.8278	0.983
75	4.6875	3.3146	4.7750	4.6500	4.7563	4.5101	4.7500	4.6250	4.6438	4.8859	4.8873	4.8893	0.983
76	4.7500	3.3588	4.8375	4.7125	4.8188	4.5736	4.8125	4.6875	4.7063	4.9494	4.9508	4.9528	0.983
77	4.8125	3.4030	4.9000	4.7750	4.8813	4.6351	4.8750	4.7500	4.7688	5.0109	5.0123	5.0143	0.984
78	4.8750	3.4471	4.9625	4.8375	4.9438	4.6986	4.9375	4.8125	4.8313	5.0744	5.0758	5.0778	0.984
79	4.9375	3.4913	5.0250	4.9000	5.0063	4.7601	5.0000	4.8750	4.8938	5.1360	5.1374	5.1394	0.984
80	5.0000	3.5355	5.0875	4.9625	5.0688	4.8236	5.0625	4.9375	4.9563	5.1995	5.2009	5.2029	0.984
81	5.0625	3.5797	5.1500	5.0250	5.1313	4.8852	5.1250	5.0000	5.0188	5.2610	5.2624	5.2644	0.984
82	5.1250	3.6239	5.2125	5.0875	5.1938	4.9486	5.1875	5.0625	5.0813	5.3245	5.3259	5.3279	0.985
83	5.1875	3.6681	5.2750	5.1500	5.2563	5.0102	5.2500	5.1250	5.1438	5.3860	5.3874	5.3894	0.985
84	5.2500	3.7123	5.3375	5.2125	5.3188	5.0736	5.3125	5.1875	5.2063	5.4495	5.4509	5.4529	0.985
85	5.3125	3.7565	5.4000	5.2750	5.3813	5.1352	5.3750	5.2500	5.2688	5.5111	5.5125	5.5145	0.985
86	5.3750	3.8007	5.4625	5.3375	5.4438	5.1986	5.4375	5.3125	5.3313	5.5745	5.5759	5.5779	0.985
87	5.4375	3.8449	5.5250	5.4000	5.5063	5.2603	5.5000	5.3750	5.3938	5.6361	5.6375	5.6395	0.985
88	5.5000	3.8891	5.5875	5.4625	5.5688	5.3336	5.5625	5.4375	5.4563	5.6995	5.7009	5.7029	0.985
89	5.5625	3.9333	5.6500	5.5250	5.6313	5.3853	5.6250	5.5000	5.5188	5.7611	5.7625	5.7645	0.986
90	5.6250	3.9775	5.7125	5.5875	5.6938	5.4487	5.6875	5.5625	5.5813	5.8245	5.8259	5.8279	0.986
91	5.6875	4.0217	5.7750	5.6500	5.7563	5.5103	5.7500	5.6250	5.6438	5.8862	5.8876	5.8896	0.986
92	5.7500	4.0659	5.8375	5.7125	5.8188	5.5737	5.8125	5.6875	5.7063	5.9495	5.9509	5.9529	0.986
93	5.8125	4.1101	5.9000	5.7750	5.8813	5.6353	5.8750	5.7500	5.7688	6.0112	6.0126	6.0146	0.986
94	5.8750	4.1543	5.9625	5.8375	5.9438	5.6988	5.9375	5.8125	5.8313	6.0746	6.0760	6.0780	0.986
95	5.9375	4.1984	6.0250	5.9000	6.0063	5.7605	6.0000	5.8750	5.8938	6.1362	6.1376	6.1396	0.986
96	6.0000	4.2426	6.0875	5.9625	6.0688	5.8238	6.0625	5.9375	5.9564	6.1996	6.2010	6.2030	0.987
97	6.0625	4.2868	6.1500	6.0250	6.1313	5.8855	6.1250	6.0000	6.0188	6.2613	6.2627	6.2647	0.987
98	6.1250	4.3310	6.2125	6.0875	6.1938	5.9488	6.1875	6.0625	6.0813	6.3245	6.3259	6.3279	0.987
99	6.1875	4.3752	6.2750	6.1500	6.2563	6.0105	6.2500	6.1250	6.1438	6.3862	6.3876	6.3896	0.987
100	6.2500	4.4194	6.3375	6.2125	6.3188	6.0738	6.3125	6.1875	6.2063	6.4495	6.4509	6.4529	0.987

TABLE 6—*24/48 Diametral Pitch*[a]

24/48 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.1309 Circular Tooth Thickness, 0.0738	Addendum, External, 0.0208 Addendum, Internal, 0.0125
Cutting-tool radius, 0.019	Measuring-pin diameter, internal and external, 0.0800	

INT AND EXT			INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance⟶			+0.0040 −0.0000	+0.0040 −0.0000		Max	+0.0000 −0.0040	+0.0000 −0.0040		Min	Min	Min	
6	0.2500	0.1768	0.3083	0.2250	0.2958	0.1289	0.2917	0.2083	0.2208	0.3790	0.3803	0.3821	0.872
7	0.2917	0.2062	0.3500	0.2667	0.3375	0.1652	0.3333	0.2500	0.2625	0.4124	0.4137	0.4155	0.884
8	0.3333	0.2357	0.3917	0.3083	0.3792	0.2138	0.3750	0.2917	0.3042	0.4630	0.4644	0.4662	0.893
9	0.3750	0.2652	0.4333	0.3500	0.4208	0.2508	0.4167	0.3333	0.3458	0.4985	0.4999	0.5017	0.901
10	0.4167	0.2946	0.4750	0.3917	0.4625	0.2979	0.4583	0.3750	0.3875	0.5469	0.5483	0.5501	0.908
11	0.4583	0.3241	0.5167	0.4333	0.5042	0.3355	0.5000	0.4167	0.4292	0.5836	0.5850	0.5868	0.914
12	0.5000	0.3536	0.5583	0.4750	0.5458	0.3817	0.5417	0.4583	0.4708	0.6306	0.6320	0.6338	0.919
13	0.5417	0.3830	0.6000	0.5167	0.5875	0.4197	0.5833	0.5000	0.5125	0.6680	0.6695	0.6713	0.924
14	0.5833	0.4125	0.6417	0.5583	0.6292	0.4653	0.6250	0.5417	0.5542	0.7141	0.7156	0.7174	0.928
15	0.6250	0.4419	0.6833	0.6000	0.6708	0.5039	0.6667	0.5833	0.5958	0.7522	0.7536	0.7555	0.931
16	0.6667	0.4714	0.7250	0.6417	0.7125	0.5489	0.7083	0.6250	0.6375	0.7977	0.7991	0.8010	0.935
17	0.7083	0.5009	0.7667	0.6833	0.7542	0.5877	0.7500	0.6667	0.6792	0.8362	0.8376	0.8395	0.938
18	0.7500	0.5303	0.8083	0.7250	0.7958	0.6324	0.7917	0.7083	0.7208	0.8812	0.8826	0.8845	0.941
19	0.7917	0.5598	0.8500	0.7667	0.8358	0.6715	0.8333	0.7500	0.7625	0.9201	0.9215	0.9234	0.943
20	0.8333	0.5893	0.8917	0.8083	0.8792	0.7158	0.8750	0.7917	0.8042	0.9647	0.9661	0.9680	0.945
21	0.8750	0.6187	0.9333	0.8500	0.9208	0.7552	0.9167	0.8333	0.8458	1.0039	1.0053	1.0072	0.948
22	0.9167	0.6482	0.9750	0.8917	0.9667	0.7993	0.9583	0.8750	0.8875	1.0482	1.0496	1.0515	0.950
23	0.9583	0.6776	1.0167	0.9333	1.0042	0.8388	1.0000	0.9167	0.9292	1.0875	1.0889	1.0908	0.951
24	1.0000	0.7071	1.0583	0.9750	1.0458	0.8826	1.0417	0.9583	0.9708	1.1316	1.1330	1.1349	0.953
25	1.0417	0.7366	1.1000	1.0167	1.0875	0.9223	1.0833	1.0000	1.0125	1.1711	1.1726	1.1745	0.955
26	1.0833	0.7660	1.1417	1.0583	1.1291	0.9660	1.1250	1.0417	1.0542	1.2150	1.2165	1.2184	0.956
27	1.1250	0.7955	1.1833	1.1000	1.1708	1.0058	1.1667	1.0833	1.0958	1.2547	1.2562	1.2581	0.958
28	1.1667	0.8250	1.2250	1.1417	1.2125	1.0494	1.2083	1.1250	1.1375	1.2983	1.2998	1.3017	0.959
29	1.2083	0.8544	1.2667	1.1833	1.2542	1.0894	1.2500	1.1667	1.1792	1.3381	1.3396	1.3415	0.960
30	1.2500	0.8839	1.3083	1.2250	1.2958	1.1328	1.2917	1.2083	1.2208	1.3817	1.3832	1.3851	0.961
31	1.2917	0.9133	1.3500	1.2667	1.3375	1.1728	1.3333	1.2500	1.2625	1.4217	1.4232	1.4251	0.962
32	1.3333	0.9428	1.3917	1.3083	1.3792	1.2162	1.3750	1.2917	1.3042	1.4651	1.4666	1.4685	0.963
33	1.3750	0.9723	1.4333	1.3500	1.4208	1.2563	1.4167	1.3333	1.3458	1.5052	1.5067	1.5086	0.964
34	1.4167	1.0017	1.4750	1.3917	1.4625	1.2996	1.4583	1.3750	1.3875	1.5485	1.5500	1.5519	0.965
35	1.4583	1.0312	1.5167	1.4333	1.5042	1.3398	1.5000	1.4167	1.4292	1.5886	1.5901	1.5920	0.966
36	1.5000	1.0607	1.5583	1.4750	1.5458	1.3828	1.5417	1.4583	1.4708	1.6319	1.6334	1.6353	0.967
37	1.5417	1.0901	1.6000	1.5167	1.5875	1.4232	1.5833	1.5000	1.5125	1.6721	1.6736	1.6755	0.968
38	1.5833	1.1196	1.6417	1.5583	1.6292	1.4663	1.6250	1.5417	1.5542	1.7152	1.7167	1.7186	0.968
39	1.6250	1.1490	1.6833	1.6000	1.6708	1.5067	1.6667	1.5833	1.5958	1.7556	1.7571	1.7590	0.969
40	1.6667	1.1785	1.7250	1.6417	1.7125	1.5496	1.7083	1.6250	1.6375	1.7986	1.8001	1.8020	0.970
41	1.7083	1.2080	1.7667	1.6833	1.7542	1.5901	1.7500	1.6667	1.6792	1.8390	1.8405	1.8424	0.971
42	1.7500	1.2374	1.8083	1.7250	1.7958	1.6331	1.7917	1.7083	1.7208	1.8820	1.8835	1.8854	0.971
43	1.7917	1.2669	1.8500	1.7667	1.8358	1.6736	1.8333	1.7500	1.7625	1.9224	1.9239	1.9258	0.972
44	1.8333	1.2964	1.8917	1.8083	1.8792	1.7164	1.8750	1.7917	1.8042	1.9654	1.9669	1.9688	0.972
45	1.8750	1.3258	1.9333	1.8500	1.9208	1.7570	1.9167	1.8333	1.8458	2.0059	2.0074	2.0093	0.973
46	1.9167	1.3553	1.9750	1.8917	1.9667	1.7998	1.9583	1.8750	1.8875	2.0487	2.0502	2.0521	0.973
47	1.9583	1.3848	2.0167	1.9333	2.0042	1.8404	2.0000	1.9167	1.9292	2.0893	2.0908	2.0927	0.974
48	2.0000	1.4142	2.0583	1.9750	2.0458	1.8832	2.0417	1.9583	1.9708	2.1321	2.1336	2.1355	0.974
49	2.0417	1.4437	2.1000	2.0167	2.0875	1.9238	2.0833	2.0000	2.0125	2.1727	2.1742	2.1761	0.975
50	2.0833	1.4731	2.1417	2.0583	2.1291	1.9665	2.1250	2.0417	2.0542	2.2154	2.2169	2.2188	0.975

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.

(*Continued on next page.*)

TABLE 6—*24/48 Diametral Pitch (Concluded)*

24/48 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.1309 Circular Tooth Thickness, 0.0738	Addendum, External, 0.0208 Addendum, Internal, 0.0125
Cutting-tool radius, 0.019	Measuring-pin diameter, internal and external, 0.0800	

INT AND EXT			INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance⟶			+0.0040 −0.0000	+0.0040 −0.0000		Max	+0.0000 −0.0040	+0.0000 −0.0040		Min	Min	Min	
51	2.1250	1.5026	2.1833	2.1000	2.1708	2.0072	2.1667	2.0833	2.0958	2.2561	2.2575	2.2595	0.976
52	2.1667	1.5321	2.2250	2.1417	2.2125	2.0499	2.2083	2.1250	2.1375	2.2988	2.3002	2.3022	0.976
53	2.2083	1.5615	2.2667	2.1833	2.2542	2.0906	2.2500	2.1667	2.1792	2.3395	2.3409	2.3429	0.977
54	2.2500	1.5910	2.3083	2.2250	2.2958	2.1332	2.2917	2.2083	2.2208	2.3822	2.3836	2.3856	0.977
55	2.2917	1.6205	2.3500	2.2667	2.3375	2.1739	2.3333	2.2500	2.2625	2.4229	2.4243	2.4263	0.977
56	2.3333	1.6499	2.3917	2.3083	2.3792	2.2165	2.3750	2.2917	2.3042	2.4655	2.4669	2.4689	0.978
57	2.3750	1.6794	2.4333	2.3500	2.4208	2.2573	2.4167	2.3333	2.3458	2.5063	2.5077	2.5097	0.978
58	2.4167	1.7088	2.4750	2.3917	2.4625	2.2998	2.4583	2.3750	2.3875	2.5489	2.5503	2.5523	0.979
59	2.4583	1.7383	2.5167	2.4333	2.5042	2.3406	2.5000	2.4167	2.4292	2.5897	2.5911	2.5931	0.979
60	2.5000	1.7678	2.5583	2.4750	2.5458	2.3831	2.5417	2.4583	2.4708	2.6322	2.6336	2.6356	0.979
61	2.5417	1.7972	2.6000	2.5167	2.5875	2.4240	2.5833	2.5000	2.5125	2.6730	2.6744	2.6764	0.980
62	2.5833	1.8267	2.6417	2.5583	2.6292	2.4665	2.6250	2.5417	2.5542	2.7156	2.7170	2.7190	0.980
63	2.6250	1.8562	2.6833	2.6000	2.6708	2.5073	2.6667	2.5833	2.5958	2.7564	2.7579	2.7598	0.980
64	2.6667	1.8856	2.7250	2.6417	2.7125	2.5498	2.7083	2.6250	2.6375	2.7989	2.8003	2.8023	0.980
65	2.7083	1.9151	2.7667	2.6833	2.7542	2.5907	2.7500	2.6667	2.6792	2.8398	2.8412	2.8432	0.981
66	2.7500	1.9445	2.8083	2.7250	2.7958	2.6332	2.7917	2.7083	2.7208	2.8823	2.8837	2.8857	0.981
67	2.7917	1.9740	2.8500	2.7667	2.8358	2.6741	2.8333	2.7500	2.7625	2.9232	2.9246	2.9266	0.981
68	2.8333	2.0035	2.8917	2.8083	2.8792	2.7165	2.8750	2.7917	2.8042	2.9656	2.9670	2.9690	0.982
69	2.8750	2.0329	2.9333	2.8500	2.9208	2.7574	2.9167	2.8333	2.8458	3.0065	3.0079	3.0099	0.982
70	2.9167	2.0624	2.9750	2.8917	2.9667	2.7999	2.9583	2.8750	2.8875	3.0490	3.0504	3.0524	0.982
71	2.9583	2.0919	3.0167	2.9333	3.0042	2.8409	3.0000	2.9167	2.9292	3.0899	3.0193	3.0933	0.982
72	3.0000	2.1213	3.0583	2.9750	3.0458	2.8833	3.0417	2.9583	2.9708	3.1323	3.1337	3.1357	0.982
73	3.0417	2.1508	3.1000	3.0167	3.0875	2.9243	3.0833	3.0000	3.0125	3.1733	3.1747	3.1767	0.983
74	3.0833	2.1802	3.1417	3.0583	3.1291	2.9666	3.1250	3.0417	3.0542	3.2157	3.2171	3.2191	0.983
75	3.1250	2.2097	3.1833	3.1000	3.1708	3.0076	3.1667	3.0833	3.0958	3.2566	3.2580	3.2600	0.983
76	3.1667	2.2392	3.2250	3.1417	3.2125	3.0500	3.2083	3.1250	3.1375	3.2990	3.3004	3.3024	0.983
77	3.2083	2.2686	3.2667	3.1833	3.2542	3.0910	3.2500	3.1667	3.1792	3.3400	3.3414	3.3434	0.984
78	3.2500	2.2981	3.3083	3.2250	3.2958	3.1333	3.2917	3.2083	3.2208	3.3824	3.3838	3.3858	0.984
79	3.2917	2.3276	3.3500	3.2667	3.3375	3.1743	3.3333	3.2500	3.2625	3.4234	3.4248	3.4268	0.984
80	3.3333	2.3570	3.3917	3.3083	3.3792	3.2167	3.3750	3.2917	3.3042	3.4657	3.4671	3.4691	0.984
81	3.3750	2.3865	3.4333	3.3500	3.4208	3.2577	3.4167	3.3333	3.3458	3.5067	3.5081	3.5101	0.984
82	3.4167	2.4159	3.4750	3.3917	3.4625	3.3000	3.4583	3.3750	3.3875	3.5489	3.5504	3.5524	0.985
83	3.4583	2.4454	3.5167	3.4333	3.5042	3.3410	3.5000	3.4167	3.4292	3.5900	3.5915	3.5935	0.985
84	3.5000	2.4749	3.5583	3.4750	3.5458	3.3833	3.5417	3.4583	3.4708	3.6322	3.6337	3.6357	0.985
85	3.5417	2.5043	3.6000	3.5167	3.5875	3.4244	3.5833	3.5000	3.5125	3.6732	3.6747	3.6767	0.985
86	3.5833	2.5338	3.6417	3.5583	3.6292	3.4667	3.6250	3.5417	3.5542	3.7155	3.7170	3.7190	0.985
87	3.6250	2.5633	3.6833	3.6000	3.6708	3.5077	3.6667	3.5833	3.5958	3.7566	3.7581	3.7601	0.985
88	3.6667	2.5927	3.7250	3.6417	3.7125	3.5500	3.7083	3.6250	3.6375	3.7989	3.8004	3.8024	0.985
89	3.7083	2.6222	3.7667	3.6833	3.7542	3.5911	3.7500	3.6667	3.6792	3.8402	3.8417	3.8437	0.986
90	3.7500	2.6517	3.8083	3.7250	3.7958	3.6333	3.7917	3.7083	3.7208	3.8822	3.8837	3.8857	0.986
91	3.7917	2.6811	3.8500	3.7667	3.8358	3.6744	3.8333	3.7500	3.7625	3.9233	3.9248	3.9268	0.986
92	3.8333	2.7106	3.8917	3.8083	3.8792	3.7167	3.8750	3.7917	3.8042	3.9656	3.9671	3.9691	0.986
93	3.8750	2.7400	3.9333	3.8500	3.9208	3.7578	3.9167	3.8333	3.8458	4.0067	4.0082	4.0102	0.986
94	3.9167	2.7695	3.9750	3.8917	3.9667	3.8000	3.9583	3.8750	3.8875	4.0489	4.0504	4.0524	0.986
95	3.9583	2.7990	4.0167	3.9333	4.0042	3.8412	4.0000	3.9167	3.9292	4.0900	4.0915	4.0935	0.986
96	4.0000	2.8284	4.0583	3.9750	4.0458	3.8834	4.0417	3.9583	3.9708	4.1322	4.1337	4.1357	0.987
97	4.0417	2.8579	4.1000	4.0167	4.0875	3.9245	4.0833	4.0000	4.0125	4.1734	4.1749	4.1769	0.987
98	4.0833	2.8874	4.1417	4.0583	4.1291	3.9668	4.1250	4.0417	4.0542	4.2156	4.2171	4.2191	0.987
99	4.1250	2.9168	4.1833	4.1000	4.1708	4.0080	4.1667	4.0833	4.0958	4.2567	4.2582	4.2602	0.987
100	4.1667	2.9463	4.2250	4.1417	4.2125	4.0501	4.2083	4.1250	4.1375	4.2989	4.3004	4.3024	0.987

TABLE 7—*32/64 Diametral Pitch*[a]

32/64 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.0982 Circular Tooth Thickness, 0.0553	Addendum, External, 0.0156 Addendum, Internal, 0.0094
Cutting-tool radius, 0.014	Measuring-pin diameter, internal and external, 0.0600	

	INT AND EXT		INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance→			+0.0030 −0.0000	+0.0030 −0.0000		Max	+0.0000 −0.0030	+0.0000 −0.0030		Min	Min	Min	
6	0.1875	0.1326	0.2313	0.1688	0.2219	0.0976	0.2188	0.1563	0.1656	0.2836	0.2849	0.2867	0.872
7	0.2188	0.1547	0.2625	0.2000	0.2531	0.1247	0.2500	0.1875	0.1969	0.3087	0.3100	0.3118	0.884
8	0.2500	0.1768	0.2938	0.2313	0.2844	0.1611	0.2813	0.2188	0.2281	0.3466	0.3479	0.3497	0.893
9	0.2813	0.1989	0.3250	0.2625	0.3156	0.1889	0.3125	0.2500	0.2594	0.3732	0.3745	0.3763	0.901
10	0.3125	0.2209	0.3563	0.2938	0.3469	0.2242	0.3438	0.2813	0.2906	0.4094	0.4108	0.4126	0.908
11	0.3438	0.2431	0.3875	0.3250	0.3781	0.2524	0.3750	0.3125	0.3219	0.4370	0.4383	0.4402	0.914
12	0.3750	0.2651	0.4188	0.3563	0.4094	0.2869	0.4063	0.3438	0.3531	0.4722	0.4735	0.4754	0.919
13	0.4063	0.2873	0.4500	0.3875	0.4406	0.3155	0.4375	0.3750	0.3844	0.5004	0.5017	0.5036	0.924
14	0.4375	0.3094	0.4813	0.4188	0.4719	0.3496	0.4688	0.4063	0.4156	0.5350	0.5363	0.5382	0.928
15	0.4688	0.3315	0.5125	0.4500	0.5031	0.3786	0.5000	0.4375	0.4469	0.5634	0.5648	0.5667	0.931
16	0.5000	0.3536	0.5438	0.4813	0.5344	0.4123	0.5313	0.4688	0.4781	0.5976	0.5990	0.6009	0.935
17	0.5313	0.3757	0.5750	0.5125	0.5656	0.4415	0.5625	0.5000	0.5094	0.6264	0.6278	0.6297	0.938
18	0.5625	0.3978	0.6063	0.5438	0.5969	0.4749	0.5938	0.5313	0.5406	0.6602	0.6616	0.6635	0.941
19	0.5938	0.4199	0.6375	0.5750	0.6281	0.5043	0.6250	0.5625	0.5719	0.6893	0.6907	0.6926	0.943
20	0.6250	0.4419	0.6688	0.6063	0.6594	0.5374	0.6562	0.5938	0.6031	0.7229	0.7242	0.7261	0.945
21	0.6563	0.4640	0.7000	0.6375	0.6906	0.5672	0.6875	0.6250	0.6344	0.7532	0.7536	0.7555	0.948
22	0.6875	0.4861	0.7313	0.6688	0.7219	0.6002	0.7188	0.6563	0.6656	0.7854	0.7868	0.7887	0.950
23	0.7188	0.5082	0.7625	0.7000	0.7531	0.6298	0.7500	0.6875	0.6969	0.8149	0.8163	0.8182	0.951
24	0.7500	0.5303	0.7938	0.7313	0.7844	0.6626	0.7813	0.7188	0.7281	0.8480	0.8494	0.8513	0.953
25	0.7813	0.5524	0.8250	0.7625	0.8156	0.6925	0.8125	0.7500	0.7594	0.8776	0.8791	0.8810	0.955
26	0.8125	0.5745	0.8563	0.7938	0.8469	0.7252	0.8438	0.7813	0.7906	0.9105	0.9120	0.9139	0.956
27	0.8438	0.5966	0.8875	0.8250	0.8781	0.7551	0.8750	0.8125	0.8219	0.9402	0.9417	0.9436	0.958
28	0.8750	0.6187	0.9188	0.8563	0.9094	0.7877	0.9063	0.8438	0.8531	0.9730	0.9745	0.9764	0.959
29	0.9063	0.6408	0.9500	0.8875	0.9406	0.8177	0.9375	0.8750	0.8844	1.0029	1.0044	1.0063	0.960
30	0.9375	0.6629	0.9813	0.9188	0.9719	0.8503	0.9688	0.9063	0.9156	1.0356	1.0371	1.0390	0.961
31	0.9688	0.6850	1.0125	0.9500	1.0031	0.8803	1.0000	0.9375	0.9469	1.0656	1.0671	1.0690	0.962
32	1.0000	0.7071	1.0438	0.9813	1.0344	0.9128	1.0313	0.9688	0.9781	1.0981	1.0996	1.1015	0.963
33	1.0313	0.7292	1.0750	1.0125	1.0656	0.9430	1.0625	1.0000	1.0094	1.1282	1.1297	1.1316	0.964
34	1.0625	0.7513	1.1063	1.0438	1.0969	0.9754	1.0938	1.0313	1.0406	1.1607	1.1622	1.1641	0.965
35	1.0938	0.7734	1.1375	1.0750	1.1281	1.0056	1.1250	1.0625	1.0719	1.1908	1.1923	1.1942	0.966
36	1.1250	0.7955	1.1688	1.1063	1.1594	1.0379	1.1563	1.0938	1.1031	1.2232	1.2247	1.2266	0.967
37	1.1563	0.8176	1.2000	1.1375	1.1906	1.0681	1.1875	1.1250	1.1344	1.2534	1.2549	1.2568	0.968
38	1.1875	0.8397	1.2313	1.1688	1.2219	1.1004	1.2188	1.1563	1.1656	1.2857	1.2872	1.2891	0.968
39	1.2188	0.8618	1.2625	1.2000	1.2531	1.1307	1.2500	1.1875	1.1969	1.3160	1.3175	1.3194	0.969
40	1.2500	0.8839	1.2938	1.2313	1.2844	1.1629	1.2813	1.2188	1.2281	1.3483	1.3498	1.3517	0.970
41	1.2813	0.9060	1.3250	1.2625	1.3156	1.1933	1.3125	1.2500	1.2594	1.3786	1.3801	1.3820	0.971
42	1.3125	0.9281	1.3563	1.2938	1.3469	1.2254	1.3438	1.2813	1.2906	1.4107	1.4122	1.4141	0.971
43	1.3438	0.9502	1.3875	1.3250	1.3781	1.2558	1.3750	1.3125	1.3219	1.4410	1.4425	1.4444	0.972
44	1.3750	0.9723	1.4188	1.3563	1.4094	1.2880	1.4063	1.3438	1.3531	1.4732	1.4747	1.4766	0.972
45	1.4063	0.9944	1.4500	1.3875	1.4406	1.3184	1.4375	1.3750	1.3844	1.5036	1.5051	1.5070	0.973
46	1.4375	1.0165	1.4813	1.4188	1.4719	1.3505	1.4688	1.4063	1.4156	1.5357	1.5372	1.5391	0.973
47	1.4688	1.0386	1.5125	1.4500	1.5031	1.3809	1.5000	1.4375	1.4469	1.5662	1.5677	1.5696	0.974
48	1.5000	1.0607	1.5438	1.4813	1.5344	1.4130	1.5313	1.4688	1.4781	1.5983	1.5998	1.6017	0.974
49	1.5313	1.0828	1.5750	1.5125	1.5656	1.4435	1.5625	1.5000	1.5094	1.6287	1.6302	1.6321	0.975
50	1.5625	1.1049	1.6063	1.5438	1.5969	1.4755	1.5938	1.5313	1.5406	1.6608	1.6623	1.6642	0.975
51	1.5938	1.1270	1.6375	1.5750	1.6281	1.5061	1.6250	1.5625	1.5719	1.6913	1.6927	1.6947	0.976
52	1.6250	1.1490	1.6688	1.6063	1.6594	1.5381	1.6562	1.5938	1.6031	1.7233	1.7247	1.7267	0.976
53	1.6563	1.1711	1.7000	1.6375	1.6906	1.5687	1.6875	1.6250	1.6344	1.7538	1.7552	1.7572	0.977
54	1.6875	1.1932	1.7313	1.6688	1.7219	1.6006	1.7188	1.6562	1.6656	1.7858	1.7872	1.7892	0.977
55	1.7188	1.2153	1.7625	1.7000	1.7531	1.6312	1.7500	1.6875	1.6969	1.8164	1.8178	1.8198	0.977
56	1.7500	1.2374	1.7938	1.7313	1.7844	1.6631	1.7813	1.7188	1.7281	1.8484	1.8498	1.8518	0.978
57	1.7813	1.2595	1.8250	1.7625	1.8156	1.6937	1.8125	1.7500	1.7594	1.8789	1.8803	1.8823	0.978
58	1.8125	1.2816	1.8563	1.7938	1.8469	1.7256	1.8438	1.7813	1.7906	1.9109	1.9123	1.9143	0.979
59	1.8438	1.3037	1.8875	1.8250	1.8781	1.7561	1.8750	1.8125	1.8219	1.9415	1.9429	1.9449	0.979
60	1.8750	1.3258	1.9188	1.8563	1.9094	1.7881	1.9063	1.8438	1.8531	1.9734	1.9748	1.9768	0.979

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.

TABLE 8—*40/80 Diametral Pitch*[a]

40/80 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.0785 Circular Tooth Thickness, 0.0443	Addendum, External, 0.0125 Addendum, Internal, 0.0075
Cutting-tool radius[b]	Measuring-pin diameter, internal and external, 0.0480	

INT AND EXT			INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major Diam	Minor Diam	*TIF* Diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance⟶			+0.0020 −0.0000	+0.0020 −0.0000		Max	+0.0000 −0.0020	+0.0000 −0.0020		Min	Min	Min	
6	0.1500	0.1061	0.1850	0.1350	0.1775	0.0788	0.1750	0.1250	0.1325	0.2263	0.2276	0.2294	0.872
7	0.1750	0.1237	0.2100	0.1600	0.2025	0.1004	0.2000	0.1500	0.1575	0.2464	0.2477	0.2495	0.884
8	0.2000	0.1414	0.2350	0.1850	0.2275	0.1295	0.2250	0.1750	0.1825	0.2767	0.2780	0.2798	0.893
9	0.2250	0.1591	0.2600	0.2100	0.2525	0.1517	0.2500	0.2000	0.2075	0.2980	0.2993	0.3011	0.901
10	0.2500	0.1768	0.2850	0.2350	0.2775	0.1799	0.2750	0.2250	0.2325	0.3270	0.3284	0.3302	0.908
11	0.2750	0.1944	0.3100	0.2600	0.3025	0.2025	0.3000	0.2500	0.2575	0.3490	0.3503	0.3522	0.914
12	0.3000	0.2121	0.3350	0.2850	0.3275	0.2301	0.3250	0.2750	0.2825	0.3772	0.3785	0.3804	0.919
13	0.3250	0.2298	0.3600	0.3100	0.3525	0.2529	0.3500	0.3000	0.3075	0.3997	0.4010	0.4029	0.924
14	0.3500	0.2475	0.3850	0.3350	0.3775	0.2802	0.3750	0.3250	0.3325	0.4274	0.4287	0.4306	0.928
15	0.3750	0.2652	0.4100	0.3600	0.4025	0.3034	0.4000	0.3500	0.3575	0.4501	0.4515	0.4534	0.931
16	0.4000	0.2829	0.4350	0.3850	0.4275	0.3304	0.4250	0.3750	0.3825	0.4774	0.4788	0.4807	0.935
17	0.4250	0.3005	0.4600	0.4100	0.4525	0.3537	0.4500	0.4000	0.4075	0.5005	0.5019	0.5038	0.938
18	0.4500	0.3182	0.4850	0.4350	0.4775	0.3805	0.4750	0.4250	0.4325	0.5275	0.5289	0.5308	0.941
19	0.4750	0.3359	0.5100	0.4600	0.5025	0.4040	0.5000	0.4500	0.4575	0.5508	0.5522	0.5541	0.943
20	0.5000	0.3536	0.5350	0.4850	0.5275	0.4304	0.5250	0.4750	0.4825	0.5776	0.5790	0.5809	0.945
21	0.5250	0.3712	0.5600	0.5100	0.5525	0.4543	0.5500	0.5000	0.5075	0.6011	0.6025	0.6044	0.948
22	0.5500	0.3889	0.5850	0.5350	0.5775	0.4807	0.5750	0.5250	0.5325	0.6277	0.6291	0.6310	0.950
23	0.5750	0.4066	0.6100	0.5600	0.6025	0.5043	0.6000	0.5500	0.5575	0.6513	0.6527	0.6546	0.951
24	0.6000	0.4243	0.6350	0.5850	0.6275	0.5307	0.6250	0.5750	0.5825	0.6778	0.6792	0.6811	0.953
25	0.6250	0.4419	0.6600	0.6100	0.6525	0.5545	0.6500	0.6000	0.6075	0.7014	0.7029	0.7048	0.955
26	0.6500	0.4596	0.6850	0.6350	0.6775	0.5807	0.6750	0.6250	0.6325	0.7277	0.7292	0.7311	0.956
27	0.6750	0.4773	0.7100	0.6600	0.7025	0.6046	0.7000	0.6500	0.6575	0.7516	0.7531	0.7550	0.958
28	0.7000	0.4949	0.7350	0.6850	0.7275	0.6308	0.7250	0.6750	0.6825	0.7778	0.7793	0.7812	0.959
29	0.7250	0.5126	0.7600	0.7100	0.7525	0.6547	0.7500	0.7000	0.7075	0.8017	0.8032	0.8051	0.960
30	0.7500	0.5303	0.7850	0.7350	0.7775	0.6808	0.7750	0.7250	0.7325	0.8278	0.8293	0.8312	0.961
31	0.7750	0.5480	0.8100	0.7600	0.8025	0.7048	0.8000	0.7500	0.7575	0.8518	0.8533	0.8552	0.962
32	0.8000	0.5657	0.8350	0.7850	0.8275	0.7308	0.8250	0.7750	0.7825	0.8779	0.8794	0.8813	0.963
33	0.8250	0.5833	0.8600	0.8100	0.8525	0.7549	0.8500	0.8000	0.8075	0.9019	0.9034	0.9053	0.964
34	0.8500	0.6010	0.8850	0.8350	0.8775	0.7809	0.8750	0.8250	0.8325	0.9279	0.9294	0.9313	0.965
35	0.8750	0.6187	0.9100	0.8600	0.9025	0.8050	0.9000	0.8500	0.8575	0.9520	0.9535	0.9554	0.966
36	0.9000	0.6364	0.9350	0.8850	0.9275	0.8309	0.9250	0.8750	0.8825	0.9779	0.9794	0.9813	0.967
37	0.9250	0.6541	0.9600	0.9100	0.9525	0.8550	0.9500	0.9000	0.9075	1.0021	1.0036	1.0055	0.968
38	0.9500	0.6717	0.9850	0.9350	0.9775	0.8809	0.9750	0.9250	0.9325	1.0280	1.0295	1.0314	0.968
39	0.9750	0.6894	1.0100	0.9600	1.0025	0.9051	1.0000	0.9500	0.9575	1.0521	1.0536	1.0555	0.969
40	1.0000	0.7071	1.0350	0.9850	1.0275	0.9309	1.0250	0.9750	0.9825	1.0780	1.0795	1.0814	0.970
41	1.0250	0.7248	1.0600	1.0100	1.0525	0.9552	1.0500	1.0000	1.0075	1.1022	1.1037	1.1056	0.971
42	1.0500	0.7425	1.0850	1.0350	1.0775	0.9809	1.0750	1.0250	1.0325	1.1279	1.1294	1.1313	0.971
43	1.0750	0.7601	1.1100	1.0600	1.1025	1.0052	1.1000	1.0500	1.0575	1.1522	1.1537	1.1556	0.972
44	1.1000	0.7778	1.1350	1.0850	1.1275	1.0309	1.1250	1.0750	1.0825	1.1779	1.1794	1.1813	0.972
45	1.1250	0.7955	1.1600	1.1100	1.1525	1.0552	1.1500	1.1000	1.1075	1.2022	1.2037	1.2056	0.973
46	1.1500	0.8132	1.1850	1.1350	1.1775	1.0809	1.1750	1.1250	1.1325	1.2279	1.2294	1.2313	0.973
47	1.1750	0.8309	1.2100	1.1600	1.2025	1.1053	1.2000	1.1500	1.1575	1.2523	1.2538	1.2557	0.974
48	1.2000	0.8485	1.2350	1.1850	1.2275	1.1310	1.2250	1.1750	1.1825	1.2779	1.2794	1.2813	0.974
49	1.2250	0.8662	1.2600	1.2100	1.2525	1.1553	1.2500	1.2000	1.2075	1.3023	1.3038	1.3057	0.975
50	1.2500	0.8839	1.2850	1.2350	1.2775	1.1810	1.2750	1.2250	1.2325	1.3280	1.3295	1.3314	0.976
51	1.2750	0.9015	1.3100	1.2600	1.3025	1.2055	1.3000	1.2500	1.2575	1.3524	1.3538	1.3558	0.976
52	1.3000	0.9192	1.3350	1.2850	1.3275	1.2311	1.3250	1.2750	1.2825	1.3780	1.3794	1.3814	0.976
53	1.3250	0.9369	1.3600	1.3100	1.3525	1.2555	1.3500	1.3000	1.3075	1.4024	1.4038	1.4058	0.977
54	1.3500	0.9546	1.3850	1.3350	1.3775	1.2811	1.3750	1.3250	1.3325	1.4280	1.4294	1.4314	0.977
55	1.3750	0.9723	1.4100	1.3600	1.4025	1.3055	1.4000	1.3500	1.3575	1.4524	1.4538	1.4558	0.977
56	1.4000	0.9900	1.4350	1.3850	1.4275	1.3311	1.4250	1.3750	1.3825	1.4780	1.4794	1.4814	0.978
57	1.4250	1.0076	1.4600	1.4100	1.4525	1.3555	1.4500	1.4000	1.4075	1.5025	1.5039	1.5059	0.978
58	1.4500	1.0253	1.4850	1.4350	1.4775	1.3810	1.4750	1.4250	1.4325	1.5280	1.5294	1.5314	0.979
59	1.4750	1.0430	1.5100	1.4600	1.5025	1.4055	1.5000	1.4500	1.4575	1.5525	1.5539	1.5559	0.979
60	1.5000	1.0607	1.5350	1.4850	1.5275	1.4310	1.5250	1.4750	1.4825	1.5781	1.5795	1.5815	0.979

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Radius not required for fine pitches, see Figs. 6 and 7.

TABLE 9—*48/96 Diametral Pitch*[a]

40/96 Diametral Pitch Pressure Angle, 45°	Circular Pitch, 0.0654 Circular Tooth Thickness, 0.0369	Addendum, External, 0.0104 Addendum, Internal, 0.0063
Cutting-tool radius[b]	Measuring-pin diameter, internal and external, 0.0400	

INT AND EXT			INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance⟶			+0.0020 −0.0000	+0.0020 −0.0000		Max	+0.0000 −0.0020	+0.0000 −0.0020		Min	Min	Min	
6	0.1250	0.0884	0.1542	0.1125	0.1479	0.0662	0.1459	0.1041	0.1104	0.1881	0.1894	0.1912	0.872
7	0.1459	0.1031	0.1750	0.1333	0.1688	0.0842	0.1667	0.1250	0.1313	0.2048	0.2061	0.2079	0.884
8	0.1667	0.1179	0.1959	0.1542	0.1896	0.1085	0.1875	0.1459	0.1521	0.2301	0.2314	0.2332	0.893
9	0.1875	0.1326	0.2167	0.1750	0.2104	0.1269	0.2083	0.1667	0.1729	0.2479	0.2492	0.2510	0.901
10	0.2083	0.1473	0.2375	0.1959	0.2313	0.1505	0.2292	0.1875	0.1938	0.2720	0.2734	0.2752	0.908
11	0.2292	0.1621	0.2583	0.2167	0.2521	0.1692	0.2500	0.2083	0.2146	0.2904	0.2917	0.2936	0.914
12	0.2500	0.1768	0.2792	0.2375	0.2729	0.1923	0.2709	0.2292	0.2354	0.3139	0.3152	0.3171	0.919
13	0.2709	0.1915	0.3000	0.2583	0.2938	0.2113	0.2917	0.2500	0.2563	0.3326	0.3339	0.3358	0.924
14	0.2917	0.2063	0.3209	0.2792	0.3146	0.2340	0.3125	0.2709	0.2771	0.3557	0.3570	0.3589	0.928
15	0.3125	0.2210	0.3417	0.3000	0.3354	0.2533	0.3333	0.2917	0.2979	0.3746	0.3760	0.3779	0.931
16	0.3333	0.2357	0.3625	0.3209	0.3563	0.2808	0.3542	0.3125	0.3188	0.3974	0.3988	0.4007	0.935
17	0.3542	0.2505	0.3833	0.3417	0.3771	0.2952	0.3750	0.3333	0.3396	0.4166	0.4180	0.4199	0.938
18	0.3750	0.2652	0.4042	0.3625	0.3979	0.3176	0.3959	0.3542	0.3604	0.4391	0.4405	0.4424	0.941
19	0.3959	0.2799	0.4250	0.3833	0.4188	0.3371	0.4167	0.3750	0.3813	0.4586	0.4600	0.4619	0.943
20	0.4167	0.2947	0.4459	0.4042	0.4396	0.3592	0.4375	0.3959	0.4021	0.4809	0.4823	0.4842	0.945
21	0.4375	0.3094	0.4667	0.4250	0.4604	0.3791	0.4583	0.4167	0.4229	0.5005	0.5019	0.5038	0.948
22	0.4583	0.3241	0.4875	0.4459	0.4833	0.4011	0.4792	0.4375	0.4438	0.5226	0.5240	0.5259	0.950
23	0.4792	0.3388	0.5083	0.4667	0.5021	0.4208	0.5000	0.4583	0.4646	0.5423	0.5437	0.5456	0.951
24	0.5000	0.3536	0.5292	0.4875	0.5229	0.4427	0.5209	0.4792	0.4854	0.5643	0.5657	0.5676	0.953
25	0.5209	0.3683	0.5500	0.5083	0.5438	0.4626	0.5417	0.5000	0.5063	0.5840	0.5855	0.5874	0.955
26	0.5417	0.3830	0.5709	0.5292	0.5646	0.4844	0.5625	0.5209	0.5271	0.6059	0.6074	0.6093	0.956
27	0.5625	0.3978	0.5917	0.5500	0.5854	0.5043	0.5833	0.5417	0.5479	0.6258	0.6273	0.6292	0.958
28	0.5833	0.4125	0.6125	0.5709	0.6063	0.5261	0.6042	0.5625	0.5688	0.6476	0.6491	0.6510	0.959
29	0.6042	0.4272	0.6333	0.5917	0.6271	0.5461	0.6250	0.5833	0.5896	0.6675	0.6690	0.6709	0.960
30	0.6250	0.4419	0.6542	0.6125	0.6479	0.5678	0.6459	0.6042	0.6104	0.6893	0.6908	0.6927	0.961
31	0.6459	0.4567	0.6750	0.6333	0.6688	0.5878	0.6667	0.6250	0.6313	0.7093	0.7108	0.7127	0.962
32	0.6667	0.4714	0.6959	0.6542	0.6896	0.6095	0.6875	0.6459	0.6521	0.7310	0.7325	0.7344	0.963
33	0.6875	0.4861	0.7167	0.6750	0.7104	0.6296	0.7083	0.6667	0.6729	0.7511	0.7526	0.7545	0.964
34	0.7083	0.5008	0.7375	0.6959	0.7313	0.6512	0.7292	0.6875	0.6938	0.7727	0.7742	0.7761	0.965
35	0.7292	0.5156	0.7583	0.7167	0.7521	0.6713	0.7500	0.7083	0.7146	0.7928	0.7943	0.7962	0.966
36	0.7500	0.5303	0.7792	0.7375	0.7729	0.6928	0.7709	0.7292	0.7354	0.8144	0.8159	0.8178	0.967
37	0.7709	0.5450	0.8000	0.7583	0.7938	0.7130	0.7917	0.7500	0.7563	0.8345	0.8360	0.8379	0.968
38	0.7917	0.5598	0.8209	0.7792	0.8146	0.7345	0.8125	0.7709	0.7771	0.8561	0.8576	0.8595	0.968
39	0.8125	0.5745	0.8417	0.8000	0.8354	0.7547	0.8333	0.7917	0.7979	0.8763	0.8778	0.8797	0.969
40	0.8333	0.5893	0.8625	0.8209	0.8563	0.7762	0.8542	0.8125	0.8188	0.8978	0.8993	0.9012	0.970
41	0.8542	0.6040	0.8833	0.8417	0.8771	0.7965	0.8750	0.8333	0.8396	0.9180	0.9195	0.9214	0.971
42	0.8750	0.6187	0.9042	0.8625	0.8979	0.8179	0.8959	0.8542	0.8604	0.9394	0.9409	0.9428	0.971
43	0.8959	0.6335	0.9250	0.8833	0.9178	0.8382	0.9167	0.8750	0.8813	0.9596	0.9611	0.9630	0.972
44	0.9167	0.6482	0.9459	0.9042	0.9396	0.8596	0.9375	0.8959	0.9021	0.9811	0.9826	0.9845	0.972
45	0.9375	0.6629	0.9667	0.9250	0.9604	0.8798	0.9583	0.9167	0.9229	1.0013	1.0028	1.0047	0.973
46	0.9583	0.6776	0.9875	0.9459	0.9833	0.9012	0.9792	0.9375	0.9438	1.0228	1.0243	1.0262	0.973
47	0.9792	0.6924	1.0083	0.9667	1.0021	0.9216	1.0000	0.9583	0.9646	1.0429	1.0444	1.0463	0.974
48	1.0000	0.7071	1.0292	0.9875	1.0229	0.9429	1.0209	0.9792	0.9854	1.0644	1.0659	1.0678	0.974
49	1.0209	0.7219	1.0500	1.0083	1.0438	0.9633	1.0417	1.0000	1.0063	1.0847	1.0862	1.0881	0.975
50	1.0417	0.7366	1.0709	1.0292	1.0646	0.9846	1.0625	1.0209	1.0271	1.1061	1.1076	1.1095	0.975
51	1.0625	0.7513	1.0917	1.0500	1.0854	1.0051	1.0833	1.0417	1.0479	1.1265	1.1279	1.1299	0.976
52	1.0833	0.7661	1.1125	1.0709	1.1063	1.0264	1.1042	1.0625	1.0688	1.1478	1.1492	1.1512	0.976
53	1.1042	0.7808	1.1333	1.0917	1.1271	1.0468	1.1250	1.0833	1.0896	1.1682	1.1696	1.1716	0.977
54	1.1250	0.7955	1.1542	1.1125	1.1479	1.0681	1.1459	1.1042	1.1104	1.1895	1.1909	1.1929	0.977
55	1.1459	0.8103	1.1750	1.1333	1.1688	1.0884	1.1667	1.1250	1.1313	1.2099	1.2113	1.2133	0.977
56	1.1667	0.8250	1.1959	1.1542	1.1896	1.1097	1.1875	1.1459	1.1521	1.2312	1.2326	1.2346	0.978
57	1.1875	0.8397	1.2167	1.1750	1.2104	1.1301	1.2083	1.1667	1.1729	1.2516	1.2530	1.2550	0.978
58	1.2083	0.8544	1.2375	1.1959	1.2313	1.1513	1.2292	1.1875	1.1938	1.2729	1.2743	1.2763	0.979
59	1.2292	0.8692	1.2583	1.2167	1.2521	1.1717	1.2500	1.2083	1.2146	1.2933	1.2947	1.2967	0.979
60	1.2500	0.8839	1.2792	1.2375	1.2729	1.1930	1.2709	1.2292	1.2354	1.3145	1.3159	1.3179	0.979

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.
[b] Radius not required for fine pitches, see Figs. 6 and 7.

TABLE 10—*64/128, 80/160, and 128/256 Diametral Pitches*[a]

PRESSURE ANGLE, 45°													
INT AND EXT			INTERNAL				EXTERNAL						
N	Pitch diam	Base-circle diam	Major diam	Minor diam	*TIF* diam	Meas between pins	Major diam	Minor diam	*TIF* diam	Measurement over pins			Factor *E*
	Ref	Ref	Min	Min	Min		Basic	Max	Max	Class A	Class B	Class C	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Recommended tolerance→			+0.0020 −0.0000	+0.0020 −0.0000		Max	+0.0000 −0.0020	+0.0000 −0.0020		Min	Min	Min	
64/128 Diametral Pitch Measuring-Pin Diam, 0.0300			Circular Pitch, 0.0491 Circular Tooth Thickness, 0.0277							Addendum, External, 0.0078 Addendum, Internal, 0.0047			
11	0.1719	0.1216	0.1938	0.1625	0.1891	0.1276	0.1875	0.1562	0.1609	0.2171	0.2184	0.2203	0.914
12	0.1875	0.1326	0.2094	0.1781	0.2047	0.1449	0.2031	0.1719	0.1766	0.2347	0.2360	0.2379	0.919
13	0.2031	0.1437	0.2250	0.1938	0.2203	0.1591	0.2187	0.1875	0.1922	0.2488	0.2501	0.2520	0.924
14	0.2187	0.1547	0.2406	0.2094	0.2359	0.1762	0.2344	0.2031	0.2078	0.2661	0.2674	0.2693	0.928
15	0.2344	0.1658	0.2563	0.2250	0.2516	0.1907	0.2500	0.2187	0.2234	0.2802	0.2816	0.2835	0.931
16	0.2500	0.1768	0.2719	0.2406	0.2672	0.2075	0.2656	0.2344	0.2391	0.2973	0.2987	0.3006	0.935
17	0.2656	0.1879	0.2875	0.2563	0.2828	0.2221	0.2812	0.2500	0.2547	0.3117	0.3131	0.3150	0.938
18	0.2812	0.1989	0.3031	0.2719	0.2984	0.2389	0.2969	0.2656	0.2703	0.3286	0.3300	0.3319	0.941
19	0.2969	0.2100	0.3188	0.2875	0.3141	0.2536	0.3125	0.2812	0.2859	0.3432	0.3446	0.3465	0.943
20	0.3125	0.2210	0.3344	0.3031	0.3297	0.2701	0.3281	0.2969	0.3016	0.3599	0.3613	0.3632	0.945
21	0.3281	0.2320	0.3500	0.3188	0.3453	0.2851	0.3437	0.3125	0.3172	0.3746	0.3760	0.3779	0.948
22	0.3437	0.2431	0.3656	0.3344	0.3609	0.3015	0.3594	0.3281	0.3328	0.3912	0.3926	0.3945	0.950
23	0.3594	0.2541	0.3813	0.3500	0.3766	0.3163	0.3750	0.3437	0.3485	0.4060	0.4074	0.4093	0.951
24	0.3750	0.2652	0.3969	0.3656	0.3922	0.3327	0.3906	0.3594	0.3641	0.4225	0.4239	0.4258	0.953
25	0.3906	0.2762	0.4125	0.3813	0.4078	0.3477	0.4062	0.3750	0.3797	0.4372	0.4387	0.4406	0.955
26	0.4062	0.2872	0.4281	0.3969	0.4234	0.3640	0.4219	0.3906	0.3953	0.4537	0.4552	0.4571	0.956
27	0.4219	0.2983	0.4438	0.4125	0.4391	0.3790	0.4375	0.4062	0.4109	0.4686	0.4701	0.4720	0.958
28	0.4375	0.3094	0.4594	0.4281	0.4547	0.3953	0.4531	0.4219	0.4266	0.4850	0.4865	0.4884	0.959
29	0.4531	0.3204	0.4750	0.4438	0.4703	0.4103	0.4687	0.4375	0.4422	0.4999	0.5014	0.5033	0.960
30	0.4687	0.3315	0.4906	0.4594	0.4859	0.4265	0.4844	0.4531	0.4578	0.5162	0.5177	0.5196	0.961
31	0.4844	0.3425	0.5063	0.4750	0.5016	0.4416	0.5000	0.4687	0.4734	0.5312	0.5327	0.5346	0.962
80/160 Diametral Pitch Measuring-Pin Diam, 0.0240			Circular Pitch, 0.0393 Circular Tooth Thickness, 0.0221							Addendum, External, 0.0063 Addendum, Internal, 0.0038			
11	0.1375	0.0972	0.1550	0.1300	0.1513	0.1027	0.1500	0.1250	0.1288	0.1730	0.1743	0.1762	0.914
12	0.1500	0.1061	0.1675	0.1425	0.1638	0.1165	0.1625	0.1375	0.1413	0.1872	0.1885	0.1904	0.919
13	0.1625	0.1149	0.1800	0.1550	0.1763	0.1279	0.1750	0.1500	0.1538	0.1984	0.1997	0.2016	0.924
14	0.1750	0.1237	0.1925	0.1675	0.1888	0.1415	0.1875	0.1625	0.1663	0.2122	0.2135	0.2154	0.928
15	0.1875	0.1326	0.2050	0.1800	0.2013	0.1531	0.2000	0.1750	0.1788	0.2236	0.2250	0.2269	0.931
16	0.2000	0.1414	0.2175	0.1925	0.2138	0.1666	0.2125	0.1875	0.1913	0.2372	0.2386	0.2405	0.935
17	0.2125	0.1503	0.2300	0.2050	0.2263	0.1783	0.2250	0.2000	0.2038	0.2488	0.2502	0.2521	0.938
18	0.2250	0.1591	0.2425	0.2175	0.2388	0.1916	0.2375	0.2125	0.2163	0.2623	0.2637	0.2656	0.941
19	0.2375	0.1679	0.2550	0.2300	0.2513	0.2034	0.2500	0.2250	0.2288	0.2739	0.2753	0.2772	0.943
20	0.2500	0.1768	0.2675	0.2425	0.2638	0.2166	0.2625	0.2375	0.2413	0.2873	0.2887	0.2906	0.945
21	0.2625	0.1856	0.2800	0.2550	0.2763	0.2286	0.2750	0.2500	0.2538	0.2991	0.3005	0.3024	0.948
22	0.2750	0.1944	0.2925	0.2675	0.2888	0.2418	0.2875	0.2625	0.2663	0.3124	0.3138	0.3157	0.950
23	0.2875	0.2033	0.3050	0.2800	0.3013	0.2536	0.3000	0.2750	0.2788	0.3242	0.3256	0.3275	0.951
24	0.3000	0.2121	0.3175	0.2925	0.3138	0.2667	0.3125	0.2875	0.2913	0.3374	0.3388	0.3407	0.953
25	0.3125	0.2210	0.3300	0.3050	0.3263	0.2786	0.3250	0.3000	0.3038	0.3492	0.3507	0.3526	0.955
26	0.3250	0.2298	0.3425	0.3175	0.3388	0.2918	0.3375	0.3125	0.3163	0.3623	0.3638	0.3657	0.956
27	0.3375	0.2387	0.3550	0.3300	0.3513	0.3037	0.3500	0.3250	0.3288	0.3742	0.3757	0.3776	0.958
128/256 Diametral Pitch Measuring-Pin Diam, 0.0150			Circular Pitch, 0.0246 Circular Tooth Thickness, 0.0139							Addendum, External, 0.0039 Addendum, Internal, 0.0023			
11	0.0859	0.0608	0.0968	0.0813	0.0945	0.0653	0.0937	0.0781	0.0805	0.1071	0.1084	0.1103	0.914
12	0.0937	0.0663	0.1047	0.0890	0.1023	0.0739	0.1016	0.0859	0.0883	0.1159	0.1172	0.1191	0.919
13	0.1016	0.0718	0.1125	0.0968	0.1102	0.0810	0.1094	0.0937	0.0961	0.1320	0.1243	0.1262	0.924
14	0.1094	0.0773	0.1203	0.1047	0.1180	0.0895	0.1172	0.1016	0.1039	0.1316	0.1329	0.1348	0.928
15	0.1172	0.0829	0.1281	0.1125	0.1258	0.0967	0.1250	0.1094	0.1117	0.1386	0.1400	0.1419	0.931
16	0.1250	0.0884	0.1359	0.1203	0.1336	0.1052	0.1328	0.1172	0.1195	0.1471	0.1485	0.1504	0.935
17	0.1328	0.0939	0.1438	0.1281	0.1414	0.1125	0.1406	0.1250	0.1273	0.1544	0.1558	0.1577	0.938
18	0.1406	0.0994	0.1516	0.1359	0.1492	0.1208	0.1484	0.1328	0.1352	0.1628	0.1642	0.1661	0.941
19	0.1484	0.1050	0.1594	0.1438	0.1570	0.1282	0.1563	0.1406	0.1430	0.1701	0.1715	0.1734	0.943
20	0.1563	0.1105	0.1672	0.1516	0.1648	0.1364	0.1641	0.1484	0.1508	0.1784	0.1798	0.1817	0.945
21	0.1641	0.1160	0.1750	0.1594	0.1727	0.1440	0.1719	0.1563	0.1586	0.1858	0.1872	0.1891	0.948
22	0.1719	0.1215	0.1828	0.1672	0.1805	0.1522	0.1797	0.1641	0.1664	0.1941	0.1955	0.1974	0.950
23	0.1797	0.1271	0.1906	0.1750	0.1883	0.1595	0.1875	0.1719	0.1742	0.2015	0.2029	0.2048	0.951
24	0.1875	0.1326	0.1984	0.1828	0.1961	0.1678	0.1953	0.1797	0.1820	0.2098	0.2112	0.2131	0.953

[a] The fits and tolerances suggested in this table are to be considered binding on a manufacturer or seller only when specifically agreed to in writing.

TABLE 11—*Internal Serration, Maximum Space Width*[a]

N	PIN MEAS. FACTOR[b]	DIAMETRAL PITCH 10/20 Basic Space Width	DIAMETRAL PITCH 16/32 Basic Space Width	DIAMETRAL PITCH 24/48 Basic Space Width	DIAMETRAL PITCH 32/64 40/80 48/96 64/128 80/160	BASIC SPACE WIDTH 0.0553 0.0443 0.0369 0.0277 0.0221	N	PIN MEAS. FACTOR[b]	DIAMETRAL PITCH 10/20 Basic Space Width	DIAMETRAL PITCH 16/32 Basic Space Width	DIAMETRAL PITCH 24/48 Basic Space Width	DIAMETRAL PITCH 32/64 40/80 48/96 64/128 80/160	BASIC SPACE WIDTH 0.0553 0.0443 0.0369 0.0277 0.0221
	F	0.1771	0.1107	0.0738	128/256	0.0138		*F*	0.1771	0.1107	0.0738	128/256	0.0138
6	1.389	0.0026	0.0026	0.0026	0.0026		51	1.019	0.0030	0.0028	0.0028	0.0028	
7	1.248	0.0027	0.0026	0.0026	0.0026		52	1.019	0.0030	0.0028	0.0028	0.0028	
8	1.206	0.0027	0.0026	0.0026	0.0026		53	1.018	0.0030	0.0029	0.0028	0.0028	
9	1.151	0.0027	0.0026	0.0026	0.0026		54	1.018	0.0030	0.0029	0.0028	0.0028	
10	1.143	0.0027	0.0026	0.0026	0.0026		55	1.018	0.0030	0.0029	0.0028	0.0028	
11	1.111	0.0027	0.0027	0.0026	0.0026		56	1.018	0.0030	0.0029	0.0028	0.0028	
12	1.110	0.0027	0.0027	0.0026	0.0026		57	1.018	0.0030	0.0029	0.0028	0.0028	
13	1.081	0.0027	0.9027	0.0026	0.0026		58	1.017	0.0030	0.0029	0.0028	0.0028	
14	1.089	0.0027	0.0027	0.0027	0.0026		59	1.016	0.0030	0.0029	0.0028	0.0028	
15	1.075	0.0027	0.0027	0.0027	0.0026		60	1.016	0.0030	0.0029	0.0028	0.0028	
16	1.075	0.0027	0.0027	0.0027	0.0026		61	1.016	0.0030	0.0029	0.0028	0.0028	
17	1.065	0.0027	0.0027	0.0027	0.0026		62	1.015	0.0030	0.0029	0.0028	0.0028	
18	1.065	0.0027	0.0027	0.0027	0.0026		63	1.015	0.0031	0.0029	0.0028	0.0028	
19	1.058	0.0027	0.0027	0.0027	0.0026		64	1.015	0.0031	0.0029	0.0028	0.0028	
20	1.056	0.0027	0.0027	0.0027	0.0026		65	1.015	0.0031	0.0029	0.0028	0.0028	
21	1.051	0.0028	0.0027	0.0027	0.0027		66	1.015	0.0031	0.0029	0.0028	0.0028	
22	1.051	0.0028	0.0027	0.0027	0.0027		67	1.015	0.0031	0.0029	0.0028	0.0028	
23	1.047	0.0028	0.0027	0.0027	0.0027		68	1.014	0.0031	0.0029	0.0028	0.0028	
24	1.046	0.0028	0.0027	0.0027	0.0027		69	1.014	0.0031	0.0029	0.0028	0.0028	
25	1.041	0.0028	0.0027	0.0027	0.0027		70	1.014	0.0031	0.0029	0.0029	0.0028	
26	1.041	0.0028	0.0027	0.0027	0.0027		71	1.014	0.0031	0.0029	0.0029	0.0028	
27	1.039	0.0028	0.0027	0.0027	0.0027		72	1.014	0.0031	0.0029	0.0029	0.0028	
28	1.038	0.0028	0.0027	0.0027	0.0027		73	1.013	0.0031	0.0029	0.0029	0.0028	
29	1.036	0.0028	0.0027	0.0027	0.0027		74	1.013	0.0031	0.0030	0.0029	0.0028	
30	1.036	0.0028	0.0027	0.0027	0.0027		75	1.013	0.0031	0.0030	0.0029	0.0028	
31	1.032	0.0028	0.0027	0.0027	0.0027		76	1.013	0.0031	0.0030	0.0029	0.0028	
32	1.032	0.0028	0.0028	0.0027	0.0027		77	1.013	0.0032	0.0030	0.0029	0.0028	
33	1.031	0.0028	0.0028	0.0027	0.0027		78	1.012	0.0032	0.0030	0.0029	0.0028	
34	1.031	0.0028	0.0028	0.0027	0.0027		79	1.012	0.0032	0.0030	0.0029	0.0028	
35	1.028	0.0029	0.0028	0.0027	0.0027		80	1.012	0.0032	0.0030	0.0029	0.0028	
36	1.028	0.0029	0.0028	0.0027	0.0027		81	1.012	0.0032	0.0030	0.0029	0.0028	
37	1.027	0.0029	0.0028	0.0027	0.0027		82	1.012	0.0032	0.0030	0.0029	0.0028	
38	1.027	0.0029	0.0028	0.0027	0.0027		83	1.012	0.0032	0.0030	0.0029	0.0028	
39	1.025	0.0029	0.0028	0.0027	0.0027		84	1.011	0.0032	0.0030	0.0029	0.0028	
40	1.025	0.0029	0.0028	0.0027	0.0027		85	1.011	0.0032	0.0030	0.0029	0.0028	
41	1.023	0.0029	0.0028	0.0027	0.0027		86	1.011	0.0032	0.0030	0.0029	0.0028	
42	1.023	0.0029	0.0028	0.0028	0.0027		87	1.011	0.0032	0.0030	0.0029	0.0028	
43	1.022	0.0029	0.0028	0.0028	0.0027		88	1.011	0.0032	0.0030	0.0029	0.0028	
44	1.022	0.0029	0.0028	0.0028	0.0027		89	1.011	0.0032	0.0030	0.0029	0.0028	
45	1.022	0.0029	0.0028	0.0028	0.0027		90	1.011	0.0032	0.0030	0.0029	0.0028	
46	1.022	0.0029	0.0028	0.0028	0.0027		91	1.011	0.0033	0.0030	0.0029	0.0028	
47	1.021	0.0029	0.0028	0.0028	0.0027		92	1.011	0.0033	0.0030	0.0029	0.0028	
48	1.021	0.0029	0.0028	0.0028	0.0027		93	1.011	0.0033	0.0030	0.0029	0.0028	
49	1.020	0.0030	0.0028	0.0028	0.0027		94	1.010	0.0033	0.0031	0.0029	0.0028	
50	1.020	0.0030	0.0028	0.0028	0.0027		95	1.010	0.0033	0.0031	0.0029	0.0028	
							96	1.010	0.0033	0.0031	0.0029	0.0028	
							97	1.010	0.0033	0.0031	0.0029	0.0028	
							98	1.010	0.0033	0.0031	0.0030	0.0028	
							99	1.010	0.0033	0.0031	0.0030	0.0028	
							100	1.010	0.0033	0.0031	0.0030	0.0028	

[a] Obtain maximum space width by adding the amount given to the basic space width at the head of the appropriate column. Add lead allowable error (60%) from Table 2 when required.

[b] Measurements between pins are obtained by multiplying table dimensions by factor *F* and adding result to the appropriate basic measurement in Table 12.

TABLE 12—*Basic Measurements*[a], *Between Pins, Internal*

N	½	10/20	16/32	24/48	32/64	40/80	48/96	64/128	80/160	128/256
6	3.0079	0.3008	0.1880	0.1253	0.0940	0.0752	0.0626	—	—	—
7	3.8885	0.3889	0.2430	0.1620	0.1215	0.0972	0.0810	—	—	—
8	5.0560	0.5056	0.3160	0.2107	0.1580	0.1264	0.1054	—	—	—
9	5.9470	0.5947	0.3717	0.2478	0.1859	0.1487	0.1239	—	—	—
10	7.0773	0.7077	0.4423	0.2949	0.2212	0.1769	0.1475	—	—	—
11	7.9823	0.7982	0.4989	0.3326	0.2495	0.1996	0.1663	0.1247	0.0998	0.0624
12	9.0895	0.9090	0.5680	0.3788	0.2840	0.2272	0.1894	0.1420	0.1136	0.0710
13	10.0062	1.0006	0.6254	0.4169	0.3127	0.2501	0.2085	0.1563	0.1251	0.0782
14	11.0974	1.1097	0.6936	0.4624	0.3468	0.2774	0.2312	0.1734	0.1387	0.0867
15	12.0236	1.2024	0.7515	0.5010	0.3758	0.3006	0.2505	0.1879	0.1503	0.0939
16	13.1031	1.3103	0.8189	0.5460	0.4095	0.3276	0.2780	0.2047	0.1638	0.1024
17	14.0369	1.4037	0.8773	0.5848	0.4387	0.3509	0.2924	0.2193	0.1755	0.1097
18	15.1072	1.5107	0.9442	0.6295	0.4721	0.3777	0.3148	0.2361	0.1888	0.1180
19	16.0473	1.6047	1.0030	0.6686	0.5015	0.4012	0.3343	0.2508	0.2006	0.1254
20	17.1104	1.7110	1.0694	0.7129	0.5347	0.4277	0.3565	0.2674	0.2139	0.1337
21	18.0557	1.8056	1.1285	0.7523	0.5643	0.4514	0.3762	0.2822	0.2257	0.1411
22	19.1129	1.9113	1.1946	0.7964	0.5973	0.4778	0.3982	0.2986	0.2389	0.1493
23	20.0626	2.0063	1.2539	0.8360	0.6270	0.5015	0.4180	0.3135	0.2508	0.1567
24	21.1150	2.1115	1.3197	0.8798	0.6598	0.5279	0.4399	0.3299	0.2639	0.1650
25	22.0685	2.2069	1.3793	0.9195	0.6897	0.5517	0.4598	0.3449	0.2758	0.1725
26	23.1167	2.3117	1.4448	0.9632	0.7224	0.5779	0.4816	0.3612	0.2890	0.1806
27	24.0734	2.4073	1.5046	1.0030	0.7523	0.6018	0.5015	0.3762	0.3009	0.1881
28	25.1182	2.5118	1.5699	1.0466	0.7849	0.6280	0.5233	0.3925	0.3140	0.1962
29	26.0777	2.6078	1.6298	1.0866	0.8149	0.6519	0.5433	0.4075	0.3255	0.2037
30	27.1194	2.7119	1.6950	1.1300	0.8475	0.6780	0.5650	0.4237	0.3390	0.2119
31	28.0812	2.8081	1.7551	1.1700	0.8775	0.7020	0.5850	0.4388	0.3510	—
32	29.1205	2.9121	1.8200	1.2134	0.9100	0.7280	0.6067	0.4550	0.3640	—
33	30.0847	3.0085	1.8803	1.2535	0.9402	0.7521	0.6268	0.4701	0.3761	—
34	31.1215	3.1122	1.9451	1.2968	0.9726	0.7781	0.6484	0.4863	0.3890	—
35	32.0876	3.2088	2.0055	1.3370	1.0028	0.8022	0.6685	0.5014	0.4011	—
36	33.1223	3.3122	2.0701	1.3800	1.0351	0.8281	0.6900	0.5175	—	—
37	34.0902	3.4090	2.1306	1.4204	1.0653	0.8522	0.7102	0.5327	—	—
38	35.1230	3.5123	2.1952	1.4635	1.0976	0.8781	0.7317	0.5488	—	—
39	36.0925	3.6093	2.2558	1.5039	1.1279	0.9023	0.7519	0.5639	—	—
40	37.1237	3.7124	2.3202	1.5468	1.1601	0.9281	0.7734	0.5801	—	—
41	38.0946	3.8095	2.3809	1.5873	1.1905	0.9524	0.7937	—	—	—
42	39.1243	3.9124	2.4453	1.6302	1.2226	0.9781	0.8151	—	—	—
43	40.0965	4.0097	2.5060	1.6707	1.2530	1.0024	0.8354	—	—	—
44	41.1248	4.1125	2.5703	1.7135	1.2852	1.0281	0.8568	—	—	—
45	42.0983	4.2098	2.6311	1.7541	1.3156	1.0524	0.8770	—	—	—

N	½	10/20	16/32	24/48	32/64	40/80	48/96	64/128	80/160	128/256
46	43.1253	4.3125	2.6953	1.7969	1.3477	1.0781	0.8984	—	—	—
47	44.0998	4.4100	2.7562	1.8375	1.3781	1.1025	0.9188	—	—	—
48	45.1258	4.5126	2.8204	1.8803	1.4102	1.1282	0.9401	—	—	—
49	46.1013	4.6101	2.8813	1.9209	1.4407	1.1525	0.9605	—	—	—
50	47.1262	4.7126	2.9454	1.9636	1.4727	1.1782	0.9818	—	—	—
51	48.1026	4.8103	3.0064	2.0043	1.5032	1.2026	1.0022	—	—	—
52	49.1265	4.9127	3.0704	2.0470	1.5352	1.2282	1.0235	—	—	—
53	50.1039	5.0104	3.1315	2.0877	1.5658	1.2526	1.0439	—	—	—
54	51.1269	5.1127	3.1954	2.1303	1.5977	1.2782	1.0652	—	—	—
55	52.1050	5.2105	3.2566	2.1710	1.6283	1.3026	1.0855	—	—	—
56	53.1272	5.3127	3.3205	2.2136	1.6602	1.3282	1.1068	—	—	—
57	54.1061	5.4106	3.3816	2.2544	1.6908	1.3526	1.1272	—	—	—
58	55.1275	5.5128	3.4455	2.2970	1.7228	1.3782	1.1485	—	—	—
59	56.1071	5.6107	3.5067	2.3378	1.7533	1.4027	1.1689	—	—	—
60	57.1278	5.7128	3.5705	2.3803	1.7853	1.4282	1.1902	—	—	—
61	58.1080	5.8108	3.6317	2.4212	1.8159	1.4527	1.2106	—	—	—
62	59.1280	5.9128	3.6955	2.4637	1.8478	1.4782	1.2319	—	—	—
63	60.1089	6.0109	3.7568	2.5045	1.8784	1.5027	1.2523	—	—	—
64	61.1283	6.1128	3.8205	2.5470	1.9103	1.5282	1.2735	—	—	—
65	62.1097	6.2110	3.8819	2.5879	1.9409	1.5528	1.2940	—	—	—
66	63.1285	6.3129	3.9455	2.6304						
67	64.1105	6.4111	4.0069	2.6713						
68	65.1287	6.5129	4.0705	2.7137						
69	66.1112	6.6111	4.1320	2.7546						
70	67.1289	6.7129	4.1956	2.7970						
71	68.1119	6.8112	4.2570	2.8380						
72	69.1291	6.9129	4.3206	2.8804						
73	70.1125	7.0113	4.3820	2.9214						
74	71.1293	7.1129	4.4456	2.9637						
75	72.1131	7.2113	4.5071	3.0047						
76	73.1295	7.3130	4.5706	3.0471						
77	74.1137	7.4114	4.6321	3.0881						
78	75.1296	7.5130	4.6956	3.1304						
79	76.1143	7.6114	4.7571	3.1714						
80	77.1298	7.7130	4.8206	3.2138						
81	78.1148	7.8115	4.8822	3.2548						
82	79.1299	7.9130	4.9456	3.2971						
83	80.1153	8.0115	5.0072	3.3381						
84	81.1301	8.1130	5.0706	3.3804						
85	82.1158	8.2116	5.1322	3.4215						

N	½	10/20	16/32	24/48
86	83.1302	8.3130	5.1956	3.4638
87	84.1162	8.4116	5.2573	3.5048
88	85.1303	8.5130	5.3206	3.5471
89	86.1166	8.6117	5.3823	3.5882
90	87.1304	8.7130	5.4457	3.6304
91	88.1171	8.8117	5.5073	3.6715
92	89.1305	8.9131	5.5707	3.7138
93	90.1175	9.0118	5.6323	3.7549
94	91.1306	9.1131	5.6957	3.7971
95	92.1178	9.2118	5.7574	3.8383
96	93.1308	9.3131	5.8207	3.8805
97	94.1182	9.4118	5.8824	3.9216
98	95.1308	9.5131	5.9457	3.9638
99	96.1186	9.6119	6.0074	4.0050
100	97.1309	9.7131	6.0707	4.0471

[a] Measurements over pins are obtained by multiplying table dimensions by factor E and subtracting result from the appropriate basic measurement in Table 14. Horizontal line under dimension shows limit of Tables 7 through 10. Dimensions beyond are given to extend usage to higher numbers of teeth.

TABLE 13—*External Serration, Minimum Tooth Thickness*[a]

N	Diametral Pitch	Basic Tooth Thickness	Diametral Pitch	Basic Tooth Thickness	Diametral Pitch	Basic Tooth Thickness	Diametral Pitch	Basic Tooth Thickness
	10/20	0.1771	16/32	0.1107	24/48	0.0738	32/64	0.0553
							40/80	0.0443
							48/96	0.0369
							64/128	0.0277
							80/160	0.0221
							128/256	0.0138
	Class of fit		Class of fit		Class of fit		Class of fit	
	A	B	C	A	B	C	A	B	C	A	B	C
6	37	22	2	37	22	2	32	17	+3	32	17	+3
7	37	22	2	37	22	2	32	17	+3	32	17	+3
8	37	22	2	37	22	2	32	17	+3	32	17	+3
9	37	22	2	37	22	2	32	17	+3	32	17	+3
10	38	23	3	37	22	2	32	17	+3	32	17	+3
11	38	23	3	37	22	2	32	17	+3	32	17	+3
12	38	23	3	37	22	2	32	17	+3	32	17	+3
13	38	23	3	37	22	2	32	17	+3	32	17	+3
14	38	23	3	38	23	3	32	17	+3	32	17	+3
15	38	23	3	38	23	3	32	17	+3	32	17	+3
16	38	23	3	38	23	3	32	17	+3	32	17	+3
17	38	23	3	38	23	3	32	17	+3	32	17	+3
18	38	23	3	38	23	3	32	17	+3	32	17	+3
19	38	23	3	38	23	3	32	17	+3	32	17	+3
20	38	23	3	38	23	3	32	17	+3	32	17	+3
21	38	23	3	38	23	3	32	17	+3	32	17	+3
22	38	23	3	38	23	3	32	17	+3	32	17	+3
23	38	23	3	38	23	3	32	17	+3	32	17	+3
24	38	23	3	38	23	3	32	17	+3	32	17	+3
25	39	24	4	38	23	3	32	17	+3	32	17	+3
26	39	24	4	38	23	3	32	17	+3	32	17	+3
27	39	24	4	38	23	3	32	17	+3	32	17	+3
28	39	24	4	38	23	3	33	18	+2	32	17	+3
29	39	24	4	38	23	3	33	18	+2	32	17	+3
30	39	24	4	38	23	3	33	18	+2	32	17	+3
31	39	24	4	38	23	3	33	18	+2	32	17	+3
32	39	24	4	38	23	3	33	18	+2	32	17	+3
33	39	24	4	38	23	3	33	18	+2	32	17	+3
34	39	24	4	38	23	3	33	18	+2	32	17	+3
35	39	24	4	38	23	3	33	18	+2	32	17	+3
36	39	24	4	38	23	3	33	18	+2	32	17	+3
37	39	24	4	38	23	3	33	18	+2	32	17	+3
38	39	24	4	38	23	3	33	18	+2	32	17	+3
39	39	24	4	38	23	3	33	18	+2	32	17	+3
40	39	24	4	38	23	3	33	18	+2	32	17	+3
41	39	24	4	38	23	3	33	18	+2	32	17	+3
42	40	25	5	39	24	4	33	18	+2	33	18	+2
43	40	25	5	39	24	4	33	18	+2	33	18	+2
44	40	25	5	39	24	4	33	18	+2	33	18	+2
45	40	25	5	39	24	4	33	18	+2	33	18	+2
46	40	25	5	39	24	4	33	18	+2	33	18	+2
47	40	25	5	39	24	4	33	18	+2	33	18	+2
48	40	25	5	39	24	4	33	18	+2	33	18	+2
49	40	25	5	39	24	4	33	18	+2	33	18	+2
50	40	25	5	39	24	4	33	18	+2	33	18	+2

[a] Obtain minimum tooth thickness by deducting the amount given, × 0.0001, from the basic tooth thickness at the head of the appropriate column, except where sign + precedes figure add to the basic tooth thickness. Measurements over pins are obtained by multiplying table dimensions by factor *E* and subtracting result from the appropriate basic measurement in Table 14.

(*Continued on next page.*)

TABLE 13—*External Serration, Minimum Tooth Thickness*[a] *(Concluded)*

N	Diametral Pitch	Basic Tooth Thickness	Diametral Pitch	Basic Tooth Thickness	Diametral Pitch	Basic Tooth Thickness	Diametral Pitch	Basic Tooth Thickness
							32/64	0.0553
							40/80	0.0443
	10/20	0.1771	16/32	0.1107	24/48	0.0738	48/96	0.0369
							64/128	0.0277
							80/160	0.0221
							128/256	0.0138
	Class of fit			Class of fit			Class of fit	
	A	B	C	A	B	C	A	B	C	A	B	C
51	40	25	5	39	24	4	33	18	+2	33	18	+2
52	40	25	5	39	24	4	33	18	+2	33	18	+2
53	40	25	5	39	24	4	33	18	+2	33	18	+2
54	40	25	5	39	24	4	33	18	+2	33	18	+2
55	40	25	5	39	24	4	33	18	+2	33	18	+2
56	40	25	5	39	24	4	33	18	+2	33	18	+2
57	40	25	5	39	24	4	33	18	+2	33	18	+2
58	40	25	5	39	24	4	33	18	+2	33	18	+2
59	41	26	6	39	24	4	33	18	+2	33	18	+2
60	41	26	6	39	24	4	33	18	+2	33	18	+2
61	41	26	6	39	24	4	33	18	+2	33	18	+2
62	41	26	6	39	24	4	33	18	+2	33	18	+2
63	41	26	6	39	24	4	33	18	+2	33	18	+2
64	41	26	6	39	24	4	33	18	+2	33	18	+2
65	41	26	6	39	24	4	33	18	+2	33	18	+2
66	41	26	6	39	24	4	33	18	+2	33	18	+2
67	41	26	6	39	24	4	33	18	+2	33	18	+2
68	41	26	6	39	24	4	33	18	+2	33	18	+2
69	41	26	6	39	24	4	33	18	+2	33	18	+2
70	41	26	6	40	25	5	33	18	+2	33	18	+2
71	41	26	6	40	25	5	33	18	+2	33	18	+2
72	41	26	6	40	25	5	33	18	+2	33	18	+2
73	41	26	6	40	25	5	33	18	+2	33	18	+2
74	41	26	6	40	25	5	33	18	+2	33	18	+2
75	42	27	7	40	25	5	33	18	+2	33	18	+2
76	42	27	7	40	25	5	33	18	+2	33	18	+2
77	42	27	7	40	25	5	33	18	+2	33	18	+2
78	42	27	7	40	25	5	33	18	+2	33	18	+2
79	42	27	7	40	25	5	33	18	+2	33	18	+2
80	42	27	7	40	25	5	33	18	+2	33	18	+2
81	42	27	7	40	25	5	33	18	+2	33	18	+2
82	42	27	7	40	25	5	33	18	+2	33	18	+2
83	42	27	7	40	25	5	33	18	+2	33	18	+2
84	42	27	7	40	25	5	34	19	+1	33	18	+2
85	42	27	7	40	25	5	34	19	+1	33	18	+2
86	42	27	7	40	25	5	34	19	+1	33	18	+2
87	42	27	7	40	25	5	34	19	+1	33	18	+2
88	42	27	7	40	25	5	34	19	+1	33	18	+2
89	42	27	7	40	25	5	34	19	+1	33	18	+2
90	42	27	7	40	25	5	34	19	+1	33	18	+2
91	42	27	7	40	25	5	34	19	+1	33	18	+2
92	43	28	8	40	25	5	34	19	+1	33	18	+2
93	43	28	8	40	25	5	34	19	+1	33	18	+2
94	43	28	8	40	25	5	34	19	+1	33	18	+2
95	43	28	8	40	25	5	34	19	+1	33	18	+2
96	43	28	8	40	25	5	34	19	+1	33	18	+2
97	43	28	8	40	25	5	34	19	+1	33	18	+2
98	43	28	8	41	26	6	34	19	+1	33	18	+2
99	43	28	8	41	26	6	34	19	+1	33	18	+2
100	43	28	8	41	26	6	34	19	+1	33	18	+2

[a] Obtain minimum tooth thickness by deducting the amount given, × 0.0001, from the basic tooth thickness at the head of the appropriate column, except where sign + precedes figure add to the basic tooth thickness. Measurements over pins are obtained by multiplying table dimensions by factor *E* and subtracting result from the appropriate basic measurement in Table 14.

TABLE 14—*Basic Measurements Over Pins, External*[a]

N	½	10/20	16/32	24/48	32/64	40/80	48/96	64/128	80/160	128/256
6	9.1631	0.9163	0.5727	0.3818	0.2864	0.2291	0.1909	—	—	—
7	9.9666	0.9967	0.6229	0.4152	0.3115	0.2492	0.2076	—	—	—
8	11.1820	1.1182	0.6989	0.4659	0.3494	0.2795	0.2329	—	—	—
9	12.0330	1.2033	0.7521	0.5014	0.3760	0.3008	0.2507	—	—	—
10	13.1949	1.3195	0.8247	0.5498	0.4123	0.3299	0.2749	—	—	—
11	14.0749	1.4075	0.8797	0.5865	0.4399	0.3519	0.2933	0.2200	0.1759	0.1100
12	15.2042	1.5204	0.9503	0.6335	0.4751	0.3801	0.3168	0.2376	0.1901	0.1188
13	16.1039	1.6104	1.0065	0.6710	0.5033	0.4026	0.3355	0.2517	0.2013	0.1259
14	17.2114	1.7211	1.0757	0.7171	0.5379	0.4303	0.3586	0.2690	0.2151	0.1345
15	18.1251	1.8125	1.1328	0.7552	0.5664	0.4531	0.3776	0.2832	0.2266	0.1416
16	19.2171	1.9217	1.2011	0.8007	0.6006	0.4804	0.4004	0.3003	0.2402	0.1501
17	20.1413	2.0141	1.2588	0.8392	0.6294	0.5035	0.4196	0.3147	0.2518	0.1574
18	21.2215	2.1222	1.3263	0.8842	0.6632	0.5305	0.4421	0.3316	0.2653	0.1658
19	22.1541	2.2154	1.3846	0.9231	0.6923	0.5538	0.4616	0.3462	0.2769	0.1731
20	23.2253	2.3225	1.4516	0.9677	0.7258	0.5806	0.4839	0.3629	0.2903	0.1814
21	24.1645	2.4165	1.5103	1.0069	0.7552	0.6041	0.5035	0.3776	0.3021	0.1888
22	25.2284	2.5228	1.5768	1.0512	0.7884	0.6307	0.5256	0.3942	0.3154	0.1971
23	26.1731	2.6173	1.6358	1.0905	0.8179	0.6543	0.5453	0.4090	0.3272	0.2045
24	27.2311	2.7231	1.7019	1.1346	0.8510	0.6808	0.5673	0.4255	0.3404	0.2128
25	28.1804	2.8180	1.7613	1.1742	0.8807	0.7045	0.5871	0.4403	0.3523	0.2202
26	29.2334	2.9233	1.8271	1.2181	0.9136	0.7308	0.6090	0.4568	0.3654	0.2284
27	30.1865	3.0187	1.8866	1.2578	0.9433	0.7547	0.6289	0.4717	0.3773	0.2359
28	31.2354	3.1235	1.9522	1.3015	0.9761	0.7809	0.6507	0.4881	0.3904	0.2440
29	32.1919	3.2192	2.0119	1.3413	1.0060	0.8048	0.6706	0.5030	0.4024	0.2515
30	33.2372	3.3237	2.0773	1.3849	1.0387	0.8309	0.6924	0.5193	0.4155	0.2597
31	34.1965	3.4197	2.1373	1.4249	1.0687	0.8549	0.7124	0.5343	0.4275	0.2672
32	35.2387	3.5239	2.2024	1.4683	1.1012	0.8810	0.7341	0.5506	0.4405	0.2753
33	36.2006	3.6201	2.2625	1.5084	1.1313	0.9050	0.7542	0.5657	0.4525	0.2829
34	37.2401	3.7240	2.3275	1.5517	1.1638	0.9310	0.7758	0.5819	0.4655	0.2909
35	38.2042	3.8204	2.3878	1.5918	1.1939	0.9551	0.7959	0.5970	0.4776	0.2985
36	39.2414	3.9241	2.4526	1.6351	1.2263	0.9810	0.8175	0.6131	0.4905	0.3066
37	40.2075	4.0208	2.5129	1.6753	1.2565	1.0052	0.8376	0.6283	0.5026	0.3141
38	41.2425	4.1243	2.5776	1.7184	1.2888	1.0311	0.8592	0.6444	0.5155	0.3222
39	42.2103	4.2210	2.6381	1.7588	1.3191	1.0552	0.8794	0.6596	0.5276	0.3298
40	43.2435	4.3244	2.7027	1.8018	1.3514	1.0811	0.9009	0.6757	0.5405	0.3379
41	44.2129	4.4213	2.7633	1.8422	1.3817	1.1053	0.9211	0.6909	0.5527	—
42	45.2444	4.5244	2.8277	1.8852	1.4139	1.1311	0.9426	0.7069	0.5656	—
43	46.2153	4.6215	2.8884	1.9256	1.4442	1.1554	0.9628	0.7221	0.5777	—
44	47.2453	4.7245	2.9528	1.9686	1.4764	1.1811	0.9843	0.7382	0.5906	—
45	48.2175	4.8218	3.0136	2.0091	1.5068	1.2054	1.0045	0.7534	0.6027	—
46	49.2461	4.9246	3.0779	2.0519	1.5389	1.2311	1.0260	0.7695	—	—
47	50.2195	5.0220	3.1387	2.0925	1.5694	1.2555	1.0461	0.7847	—	—
48	51.2468	5.1247	3.2029	2.1353	1.6015	1.2811	1.0676	0.8007	—	—
49	52.2213	5.2221	3.2638	2.1759	1.6319	1.3055	1.0879	0.8159	—	—
50	53.2475	5.3248	3.3279	2.2186	1.6640	1.3312	1.1093	0.8320	—	—
51	54.2230	5.4223	3.3889	2.2593	1.6945	1.3556	1.1297	—	—	—
52	55.2481	5.5248	3.4530	2.3020	1.7265	1.3812	1.1510	—	—	—
53	56.2245	5.6225	3.5140	2.3427	1.7570	1.4056	1.1714	—	—	—
54	57.2487	5.7249	3.5780	2.3854	1.7890	1.4312	1.1927	—	—	—
55	58.2260	5.8226	3.6391	2.4261	1.8196	1.4556	1.2131	—	—	—
56	59.2492	5.9249	3.7031	2.4687	1.8516	1.4812	1.2344	—	—	—
57	60.2273	6.0227	3.7642	2.5095	1.8821	1.5057	1.2548	—	—	—
58	61.2497	6.1250	3.8281	2.5521	1.9141	1.5312	1.2761	—	—	—
59	62.2286	6.2229	3.8893	2.5929	1.9447	1.5557	1.2965	—	—	—
60	63.2502	6.3250	3.9531	2.6354	1.9766	1.5813	1.3177	—	—	—
61	64.2297	6.4230	4.0144	2.6762	2.0072	1.6057	1.3381	—	—	—
62	65.2506	6.5251	4.0782	2.7188	2.0391	1.6313	1.3594	—	—	—
63	66.2308	6.6231	4.1394	2.7596	2.0697	1.6558	1.3798	—	—	—
64	67.2510	6.7251	4.2032	2.8021	2.1016	1.6813	1.4011	—	—	—
65	68.2319	6.8232	4.2645	2.8430	2.1323	1.7058	1.4215	—	—	—
66	69.2514	6.9251	4.3282	2.8855						
67	70.2328	7.0233	4.3896	2.9264						
68	71.2518	7.1252	4.4532	2.9688						
69	72.2337	7.2234	4.5146	3.0097						
70	73.2521	7.3252	4.5783	3.0522						
71	74.2346	7.4235	4.6397	3.0931						
72	75.2525	7.5253	4.7033	3.1355						
73	76.2354	7.6235	4.7647	3.1765						
74	77.2528	7.7253	4.8283	3.2189						
75	78.2362	7.8236	4.8898	3.2598						
76	79.2531	7.9253	4.9533	3.3022						
77	80.2369	8.0237	5.0148	3.3432						
78	81.2534	8.1253	5.0783	3.3856						
79	82.2376	8.2238	5.1399	3.4266						
80	83.2536	8.3254	5.2034	3.4689						
81	84.2383	8.4238	5.2649	3.5099						
82	85.2539	8.5254	5.3284	3.5522						
83	86.2389	8.6239	5.3899	3.5933						
84	87.2541	8.7254	5.4534	3.6356						
85	88.2395	8.8240	5.5150	3.6766						

N	½	10/20	16/32	24/48
86	89.2544	8.9254	5.5784	3.7189
87	90.2401	9.0240	5.6400	3.7600
88	91.2546	9.1255	5.7034	3.8023
89	92.2406	9.2241	5.7650	3.8436
90	93.2548	9.3255	5.8284	3.8856
91	94.2411	9.4241	5.8901	3.9267
92	95.2550	9.5255	5.9534	3.9690
93	96.2416	9.6242	6.0151	4.0101
94	97.2552	9.7255	6.0785	4.0523
95	98.2421	9.8242	6.1401	4.0934
96	99.2554	9.9255	6.2035	4.1356
97	100.2426	10.0243	6.2652	4.1768
98	101.2556	10.1256	6.3285	4.2190
99	102.2430	10.2243	6.3902	4.2601
100	103.2557	10.3256	6.4535	4.3023

[a] Horizontal line under dimensions shows limit of Tables 7 through 10. Dimensions beyond are given to extend usage to higher numbers of teeth.

Appendix I—Cutting Tools and Data

Hobs and Broaches—Because of manufacturing restrictions on the total number of teeth in a hob, the length of the hubs may be increased in some cases to effect a reduction in the width of cutting face.

Broach design will be in accordance with the specifications given in the tables for internal serrations. The length of the broach is determined by the length of the part, the hardness, the type of material to be broached, and the broaching equipment available.

See Figs. 6 through 13.

TABLE 15—*Recommended Hob Dimensions*

BORE→	1.2500		0.7500		0.5000		0.3150	
DP	OD	Width	OD	Width	OD	Width	OD	Width
10/20	2.500	2.500	1.750	1.750	1.250	1.250	—	—
16/32	2.500	2.500	1.750	1.750	1.250	1.250	—	—
24/48	2.500	2.500	1.750	1.750	1.250	1.250	—	—
32/64	—	—	1.500	1.500	1.125	1.125	0.750	0.500
40/80	—	—	1.500	1.500	1.125	1.125	0.750	0.500
48/96	—	—	1.500	1.500	1.125	1.125	0.750	0.500
64/128	—	—	1.500	1.500	1.125	1.125	0.750	0.500
80/160	—	—	1.500	1.500	1.125	1.125	0.750	0.500
128/256	—	—	1.500	1.500	1.125	1.125	0.750	0.500

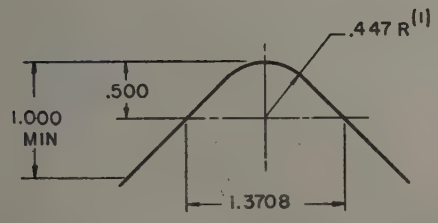


Fig. 6—½DP Hob-Tooth Form
Note 1—This dimension does not apply to 40/80 DP and finer DP.

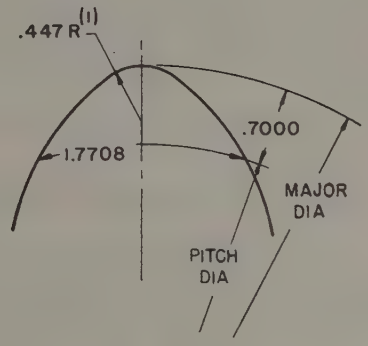


Fig. 7—½DP Broach-Tooth Form
Note 1—This dimension does not apply to 40/80 DP and finer DP

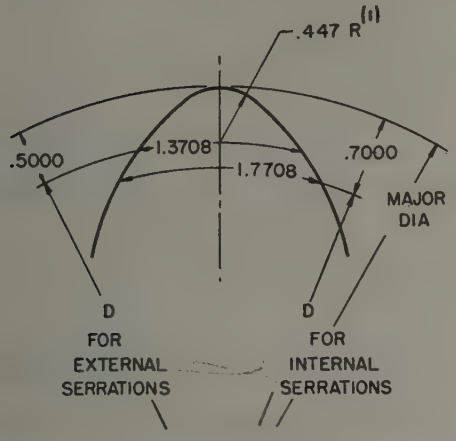


Fig. 8—½DP Shaper-Cutter Tooth Form
Note 1—This dimension does not apply to 40/80 DP and finer DP.

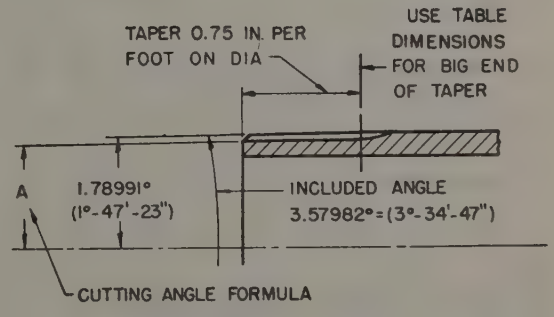


Fig. 9—Tapered Serration (See Table 16)

TABLE 16—*Angle A* (*See Fig. 9*)

N	*A*	*N*	*A*	*N*	*A*	*N*	*A*
6	1° 17′	15	1° 34′	30	1° 40′	50	1° 43′
8	1° 26′	20	1° 37′	35	1° 41′	70	1° 44′
10	1° 28′	25	1° 39′	40	1° 42′	100	1° 45′

For Fig. 9,

$$\text{Tan } A = \frac{N-1}{32(N+1)} \qquad (7)$$

Appendix II—Allowable Deviations

Straight-Sided Teeth—There are some conditions in which straight-sided serrations are acceptable, especially for the internal serration where the broach teeth may be made with sides straight instead of involute. The difference between a straight line and the involute will be called the deviation. Fig. 11 shows the deviation from a straight-sided tooth, the amount of which has been calculated for different numbers of teeth and plotted on a chart, which is Fig. 10.

Good manufacturing practice has indicated that where the deviation was 0.0015 or less, a straight-sided internal serration was acceptable and would allow the broach to be made with straight-sided teeth. Since the actual deviation on each diametral pitch must be held with 0.0015, and Fig. 10 shows the deviation for ½ diametral pitch, it is necessary for comparison to multiply 0.0015 by the diametral pitch to obtain the equivalent deviation. For example, the equivalent deviation for 24/48 diametral pitch is $0.0015 \times 24 = 0.0036$. In Fig. 10, for this deviation the number of teeth is 20; so that for 24/48 diametral pitch, serrations for 20 or less teeth should be made involute because the deviation is greater than 0.0015, and serrations of 21 or more teeth may be made with straight sides because the deviation is less than 0.0015.

Fig. 12 shows the dividing line for all diametral pitches between serrations which should be made with involute teeth and those which may be made with straight sided teeth. The maximum number of teeth in the involute zone is shown for each diametral pitch along the curve.

For Figs. 11 and 13,

$$\text{Angle } C = 90° - \frac{202.918730°}{N} \tag{8}$$

Pin Measurement—With straight-sided serrations, the pin measurements from Tables 4 to 10, inclusive (Col 7) will give slightly tighter fits than with involute sides. Correct measurements may be calculated by formulas given below:

N, even

$$M_i = \frac{D_b - d}{\sin \frac{C}{2}} - d \tag{9}$$

N, odd

$$M_i = \cos \frac{90°}{N} \left(\frac{D_b - d}{\sin \frac{C}{2}} \right) - d \tag{10}$$

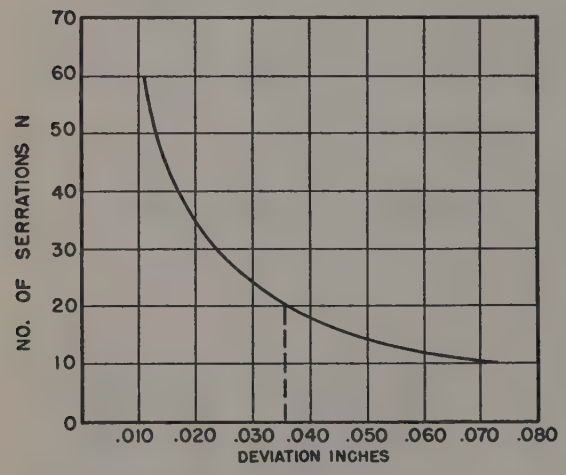


Fig. 10—Deviation from Straight Line, ½ DP

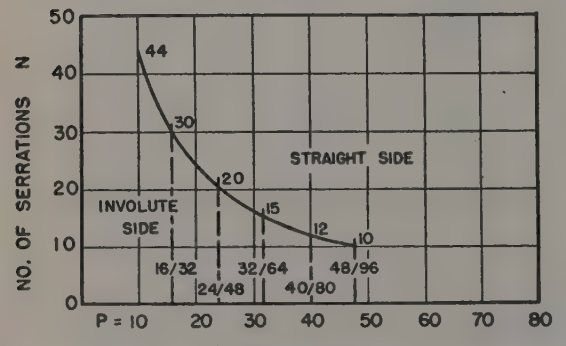


Fig. 12—Division Between Involute and Straight-Sided Teeth

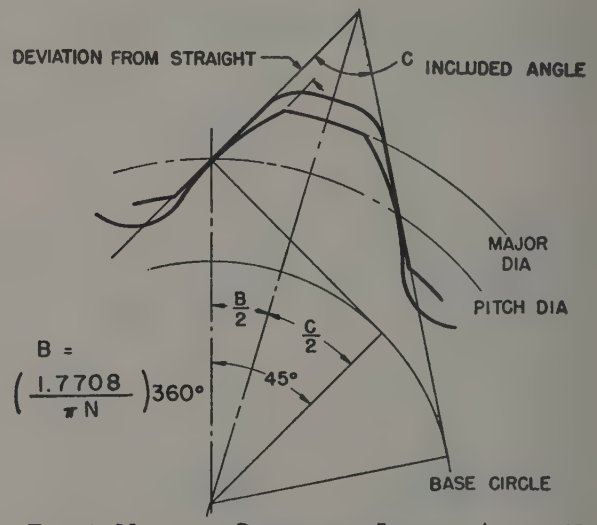


Fig. 11—Method of Determining Included Angle for Serration Teeth

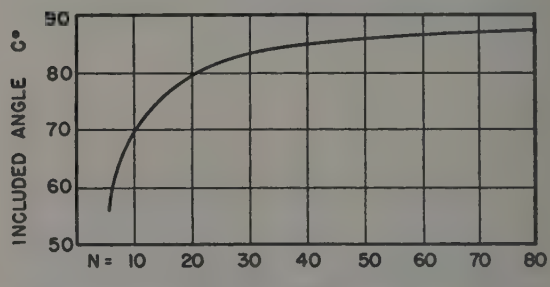


Fig. 13—Approximate Angles Obtained for C by Use of Formula (8)

Parallel-Side Splines for Soft-Broached Holes in Fittings

SAE Standard

Report of Broaches Division approved January 1914, last revised by Shaft Fittings Division March 1920, and reviewed January 1936.

[*The dimensions, given in inches, apply only to soft-broached holes. The shaft dimensions depend upon the shape and material of the parts, their heat-treatment, and methods of machining to give the required fit. The method and amount of 'breaking' sharp corners and edges also depend upon the conditions and requirements of each application.*

The formula for theoretical torque capacity (pressure on sides of spline) in inch-pounds per inch of bearing length (L) and at 1000 psi pressure is:

T = *Torque* = 1000 × *No. of splines* × *mean radius* × $h \times L$

The tolerances allowed are for good construction and may be readily maintained by usual broaching methods. The tolerances selected for the large and small diameters will depend upon whether the fit between the mating parts, as finally made, is on the large or the small diameter. The other diameter, being designed for clearance may have a wider manufacturing tolerance. If the final fit between the parts is on only the sides of the spline, wider tolerances may be permitted on both the large and small diameters.]

Radii on corners of splines are not to exceed 0.015 in.

Splines shall not be more than 0.006 in. per ft out of parallel with respect to the axis of the shaft.

No allowance is made for radii on corners or for clearance. Dimensions are intended to apply to only the soft-broached hole. Allowance must be made for machining.

For values of D, W, d, h, and T for four-, six-, ten-, and sixteen-spline fittings, see Tables 2, 3, 4, and 5, respectively.

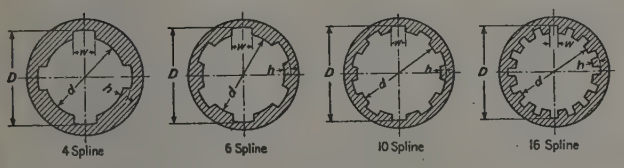


FIG. 1—DIMENSIONS FOR 4, 6, 10, AND 16 SPLINE FITTINGS (SEE TABLE 1)

TABLE 1—*W, h, and d, in Terms of Large Diameter, D*

NUMBER OF SPLINES	W, FOR ALL FITS	A, PERMANENT FIT		B, TO SLIDE NOT UNDER LOAD		C, TO SLIDE UNDER LOAD	
		h	d	h	d	h	d
4	0.241D[a]	0.075D	0.850D	0.125D	0.750D	—	—
6	0.250D	0.050D	0.900D	0.075D	0.850D	0.100D	0.800D
10	0.156D	0.045D	0.910D	0.070D	0.860D	0.095D	0.810D
16	0.098D	0.045D	0.910D	0.070D	0.860D	0.095D	0.810D

[a] Four splines, for fits A and B only.

TABLE 2—*Four-Spline Fittings*

NOMINAL DIAMETER	FOR ALL FITS				4A, PERMANENT FIT					4B, TO SLIDE WHEN NOT UNDER LOAD				
	D		W		d		h		T	d		h		T
	Min	Max	Min	Max	Min	Max	Min	Max		Min	Max	Min	Max	
¾	0.749	0.750	0.179	0.181	0.636	0.637	0.055	0.056	78	0.561	0.562	0.093	0.094	123
⅞	0.874	0.875	0.209	0.211	0.743	0.744	0.065	0.066	107	0.655	0.656	0.108	0.109	167
1	0.999	1.000	0.239	0.241	0.849	0.850	0.074	0.075	139	0.749	0.750	0.124	0.125	219
1⅛	1.124	1.125	0.269	0.271	0.955	0.956	0.083	0.084	175	0.843	0.844	0.140	0.141	277
1¼	1.249	1.250	0.299	0.301	1.061	1.062	0.093	0.094	217	0.936	0.937	0.155	0.156	341
1⅜	1.374	1.375	0.329	0.331	1.168	1.169	0.102	0.103	262	1.030	1.031	0.171	0.172	414
1½	1.499	1.500	0.359	0.361	1.274	1.275	0.111	0.112	311	1.124	1.125	0.186	0.187	491
1⅝	1.624	1.625	0.389	0.391	1.380	1.381	0.121	0.122	367	1.218	1.219	0.202	0.203	577
1¾	1.749	1.750	0.420	0.422	1.486	1.487	0.130	0.131	424	1.311	1.312	0.218	0.219	670
2	1.998	2.000	0.479	0.482	1.698	1.700	0.148	0.150	555	1.498	1.500	0.248	0.250	875
2¼	2.248	2.250	0.539	0.542	1.910	1.912	0.167	0.169	703	1.685	1.687	0.279	0.281	1106
2½	2.498	2.500	0.599	0.602	2.123	2.125	0.185	0.187	865	1.873	1.875	0.310	0.312	1365
3	2.998	3.000	0.720	0.723	2.548	2.550	0.223	0.225	1249	2.248	2.250	0.373	0.375	1969

(*Continued on next page.*)

TABLE 3—*Six-Spline Fittings*

NOMINAL DIAMETER	FOR ALL FITS				6A, PERMANENT FIT			6B, TO SLIDE WHEN NOT UNDER LOAD			6C, TO SLIDE WHEN UNDER LOAD		
	D		*W*		*d*		*T*	*d*		*T*	*d*		*T*
	Min	Max	Min	Max	Min	Max		Min	Max		Min	Max	
¾	0.749	0.750	0.186	0.188	0.674	0.675	80	0.637	0.638	117	0.599	0.600	152
⅞	0.874	0.875	0.217	0.219	0.787	0.788	109	0.743	0.744	159	0.699	0.700	207
1	0.999	1.000	0.248	0.250	0.899	0.900	143	0.849	0.850	208	0.799	0.800	270
1⅛	1.124	1.125	0.279	0.281	1.012	1.013	180	0.955	0.956	263	0.899	0.900	342
1¼	1.249	1.250	0.311	0.313	1.124	1.125	223	1.062	1.063	325	0.999	1.000	421
1⅜	1.374	1.375	0.342	0.344	1.237	1.238	269	1.168	1.169	393	1.099	1.100	510
1½	1.499	1.500	0.373	0.375	1.349	1.350	321	1.274	1.275	468	1.199	1.200	608
1⅝	1.624	1.625	0.404	0.406	1.462	1.463	376	1.380	1.381	550	1.299	1.300	713
1¾	1.749	1.750	0.436	0.438	1.574	1.575	436	1.487	1.488	637	1.399	1.400	827
2	1.998	2.000	0.497	0.500	1.798	1.800	570	1.698	1.700	833	1.598	1.600	1080
2¼	2.248	2.250	0.560	0.563	2.023	2.025	721	1.911	1.913	1052	1.798	1.800	1367
2½	2.498	2.500	0.622	0.625	2.248	2.250	891	2.123	2.125	1300	1.998	2.000	1688
3	2.998	3.000	0.747	0.750	2.698	2.700	1283	2.548	2.550	1873	2.398	2.400	2430

TABLE 4—*Ten-Spline Fittings*

NOMINAL DIAMETER	FOR ALL FITS				10A, PERMANENT FIT			10B, TO SLIDE WHEN NOT UNDER LOAD			10C, TO SLIDE WHEN UNDER LOAD		
	D		*W*		*d*		*T*	*d*		*T*	*d*		*T*
	Min	Max	Min	Max	Min	Max		Min	Max		Min	Max	
¾	0.749	0.750	0.115	0.117	0.682	0.683	120	0.644	0.645	183	0.607	0.608	241
⅞	0.874	0.875	0.135	0.137	0.795	0.796	165	0.752	0.753	248	0.708	0.709	329
1	0.999	1.000	0.154	0.156	0.909	0.910	215	0.859	0.860	326	0.809	0.810	430
1⅛	1.124	1.125	0.174	0.176	1.023	1.024	271	0.967	0.968	412	0.910	0.911	545
1¼	1.249	1.250	0.193	0.195	1.137	1.138	336	1.074	1.075	508	1.012	1.013	672
1⅜	1.374	1.375	0.213	0.215	1.250	1.251	406	1.182	1.183	614	1.113	1.114	813
1½	1.499	1.500	0.232	0.234	1.364	1.365	483	1.289	1.290	732	1.214	1.215	967
1⅝	1.624	1.625	0.252	0.254	1.478	1.479	566	1.397	1.398	860	1.315	1.316	1135
1¾	1.749	1.750	0.271	0.273	1.592	1.593	658	1.504	1.505	997	1.417	1.418	1316
2	1.998	2.000	0.309	0.312	1.818	1.820	860	1.718	1.720	1302	1.618	1.620	1720
2¼	2.248	2.250	0.348	0.351	2.046	2.048	1088	1.933	1.935	1647	1.821	1.823	2176
2½	2.498	2.500	0.387	0.390	2.273	2.275	1343	2.148	2.150	2034	2.023	2.025	2688
3	2.998	3.000	0.465	0.468	2.728	2.730	1934	2.578	2.580	2929	2.428	2.430	3869
3½	3.497	3.500	0.543	0.546	3.182	3.185	2632	3.007	3.010	3987	2.832	2.835	5266
4	3.997	4.000	0.621	0.624	3.637	3.640	3438	3.437	3.440	5208	3.237	3.240	6878
4½	4.497	4.500	0.699	0.702	4.092	4.095	4351	3.867	3.870	6591	3.642	3.645	8705
5	4.997	5.000	0.777	0.780	4.547	4.550	5371	4.297	4.300	8137	4.047	4.050	10746
5½	5.497	5.500	0.855	0.858	5.002	5.005	6500	4.727	4.730	9846	4.452	4.455	13003
6	5.997	6.000	0.933	0.936	5.457	5.460	7735	5.157	5.160	11718	4.857	4.860	15475

(*Continued on next page.*)

TABLE 5—*Sixteen-Spline Fittings*

NOMINAL DIAMETER	FOR ALL FITS				16A, PERMANENT FIT			16B, TO SLIDE WHEN NOT UNDER LOAD			16C, TO SLIDE WHEN UNDER LOAD		
	D		*W*		*d*		*T*	*d*		*T*	*d*		*T*
	Min	Max	Min	Max	Min	Max		Min	Max		Min	Max	
2	1.997	2.000	0.193	0.196	1.817	1.820	1375	1.717	1.720	2083	1.617	1.620	2751
2½	2.497	2.500	0.242	0.245	2.273	2.275	2149	2.147	2.150	3255	2.022	2.025	4299
3	2.997	3.000	0.291	0.294	2.727	2.730	3094	2.577	2.580	4687	2.427	2.430	6190
3½	3.497	3.500	0.340	0.343	3.182	3.185	4212	3.007	3.010	6378	2.832	2.835	8426
4	3.997	4.000	0.389	0.392	3.637	3.640	5501	3.437	3.440	8333	3.237	3.240	11005
4½	4.497	4.500	0.438	0.441	4.092	4.095	6962	3.867	3.870	10546	3.642	3.645	13928
5	4.997	5.000	0.487	0.490	4.547	4.550	8595	4.297	4.300	13020	4.047	4.050	17195
5½	5.497	5.500	0.536	0.539	5.002	5.005	10395	4.727	4.730	15754	4.452	4.455	20806
6	5.997	6.000	0.585	0.588	5.457	5.460	12377	5.157	5.160	18749	4.857	4.860	24760

Shaft Ends

SAE Standard

Report of Broaches Division approved June 1914 and last revised by Parts and Fittings Technical Committee May 1948.

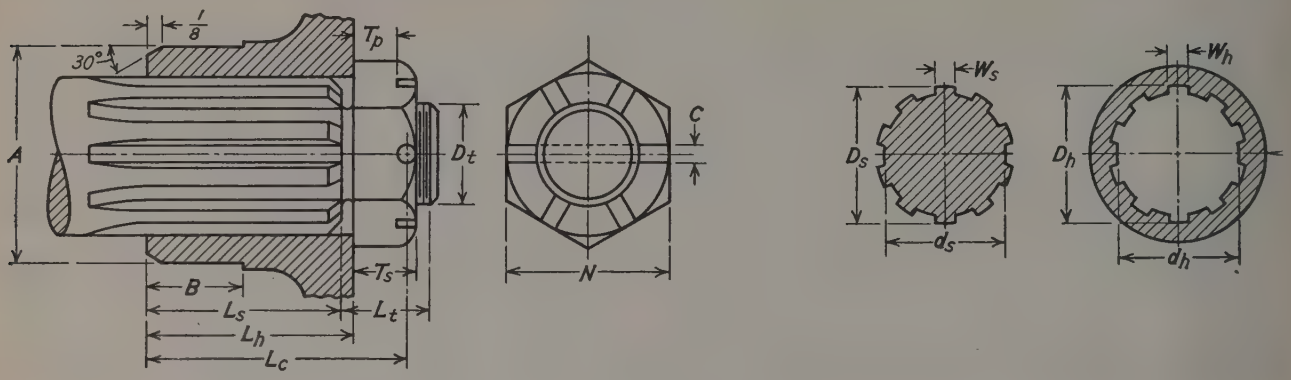


FIG. 1—PERMANENT-FIT SPLINE SHAFT ENDS (SEE TABLE 1)

TABLE 1—*Permanent-Fit Spline Shaft Ends for Universal Joints and Similar Applications*

NOM SHAFT DIAM	10-SPLINE SHAFT[a]			10-SPLINE HOLE[a]			HUB DIMENSIONS									C	A[b]	B
	D_s +0.000 −0.001	W_s +0.000 −0.0015	d_s +0.000 −0.010	D_h	W_h +0.000 −0.0015	d_h +0.010 −0.000	L_c	L_s	L_h	L_t	D_t	tpi	T_s	T_p	N			
¾	0.749	0.1170	0.632	0.751 0.749	0.1170	0.682	1 11/32	15/16	1	1 17/32	½	28	7/16	¼	1 3/16	⅛	1⅛	⅝
⅞	0.874	0.1370	0.745	0.876 0.874	0.1370	0.795	1 11/16	1⅛	1¼	1 1/16	⅝	24	½	5/16	1 5/16	5/32	1¼	¾
1	0.999	0.1560	0.859	1.001 0.999	0.1560	0.909	1 15/16	1⅜	1½	1 1/16	¾	20	½	5/16	1 1/16	5/32	1⅜	⅞
1⅛	1.124	0.1760	0.973	1.126 1.124	0.1760	1.023	1 15/16	1⅜	1½	1 1/16	⅞	20	½	5/16	1¼	5/32	1½	⅞
1¼	1.249	0.1950	1.087	1.251 1.249	0.1950	1.137	1 15/16	1⅜	1½	1 1/16	1	20	½	5/16	1 7/16	5/32	1¾	⅞
1⅜	1.374	0.2150	1.200	1.376 1.374	0.2150	1.250	2 7/16	1⅞	2	1 1/16	1	20	½	5/16	1 7/16	5/32	2	1
1½	1.499	0.2340	1.304	1.501 1.499	0.2340	1.364	2 7/16	1⅞	2	1 3/16	1¼	18	⅝	7/16	1 13/16	5/32	2¼	1
1⅝	1.624	0.2540	1.347	1.627 1.624	0.2540	1.397	2 13/16	2⅛	2¼	1 3/16	1¼	18	⅝	7/16	1 13/16	5/32	2⅜	1¼
1¾	1.749	0.2730	1.454	1.752 1.749	0.2730	1.504	2 13/16	2⅛	2¼	1 3/16	1¼	18	⅝	7/16	2 3/16	5/32	2½	1¼
2	1.999	0.3120	1.668	2.002 1.999	0.3120	1.718	3 9/16	2⅞	3	1 3/16	1¼	18	⅝	7/16	2 3/16	5/32	2¾	1½
2¼	2.249	0.3510	1.883	2.252 2.249	0.3510	1.933	3 9/16	2⅞	3	1 3/16	1½	18	⅝	7/16	2⅜	5/32	3	1½
2½	2.499	0.3900	2.098	2.502 2.499	0.3900	2.148	4 9/32	3⅜	3½	1¼	2	16	1	⅝	3⅛	7/32	3½	1¾
3	2.999	0.4680	2.528	3.002 2.999	0.4680	2.578	4 25/32	3⅞	4	1¼	2	16	1	⅝	3⅛	7/32	4	2

[a] SAE Standard Involute Spline optional.
[b] Tolerance for ground finish, nominal + 0.003, − 0.002; and when specified, the maximum eccentricity with respect to the hole shall be 0.002 (indicator reading 0.004). Tolerance for lathe finish, nominal + 1/32, − 0.

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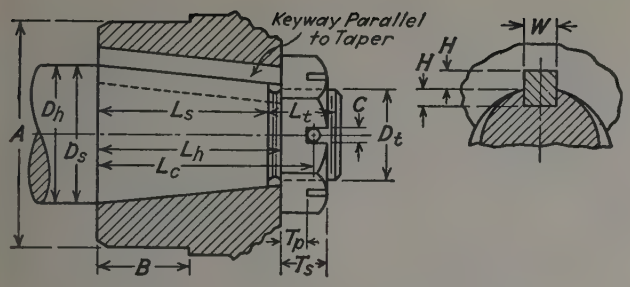


FIG. 2—TAPER SHAFT END (SEE TABLE 2)

Taper per foot = 1.500 ± 0.002 in. Dimension H is measured normal to the key and at the large end of the taper.

C = cotter-pin hole or slot. The centerline of the cotter-pin hole shall be 90 deg from the position of the keyway, as shown in Fig. 2.

TABLE 2—*Taper Shaft End*

NOM SHAFT DIAM	D_s, SHAFT DIAM		D_h, HOLE DIAM		L_c	L_s	L_h	L_t	D_t	tpi	T_s	T_p	NUT WIDTH (FLATS)	C	W		H +0.004 −0.000	SQUARE KEY		A[a]	B
	Max	Min	Max	Min											Max	Min		Max	Min		
1/4	0.250	0.249	0.248	0.247	9/16	5/16	3/8	5/16	#10	40	7/32	9/64	5/16	5/64	0.0625	0.0615	0.033	0.0635	0.0625	1/2	3/16
3/8	0.375	0.374	0.373	0.372	47/64	7/16	1/2	23/64	5/16	32	17/64	3/16	1/2	5/64	0.0937	0.0927	0.049	0.0947	0.0937	11/16	1/4
1/2	0.500	0.499	0.498	0.497	63/64	11/16	3/4	23/64	5/16	32	17/64	3/16	1/2	5/64	0.1250	0.1240	0.065	0.1260	0.1250	7/8	3/8
5/8	0.625	0.624	0.623	0.622	1 3/32	11/16	3/4	17/32	1/2	28	7/16	1/4	3/4	1/8	0.1562	0.1552	0.080	0.1572	0.1562	1 1/16	3/8
3/4	0.750	0.749	0.748	0.747	1 11/32	15/16	1	17/32	1/2	28	7/16	1/4	3/4	1/8	0.1875	0.1865	0.096	0.1885	0.1875	1 1/4	5/8
7/8	0.875	0.874	0.873	0.872	1 11/16	1 1/8	1 1/4	1 1/16	5/8	24	1/2	5/16	15/16	5/32	0.2500	0.2490	0.127	0.2510	0.2500	1 1/2	3/4
1	1.001	0.999	0.997	0.995	1 15/16	1 3/8	1 1/2	1 1/16	3/4	20	1/2	5/16	1 1/16	5/32	0.2500	0.2490	0.127	0.2510	0.2500	1 3/4	7/8
1 1/8	1.126	1.124	1.122	1.120	1 15/16	1 3/8	1 1/2	1 1/16	7/8	20	1/2	5/16	1 1/4	5/32	0.3125	0.3115	0.158	0.3135	0.3125	2	7/8
1 1/4	1.251	1.249	1.247	1.245	1 15/16	1 3/8	1 1/2	1 1/16	1	20	1/2	5/16	1 7/16	5/32	0.3125	0.3115	0.158	0.3135	0.3125	2 1/8	7/8
1 3/8	1.376	1.374	1.372	1.370	2 1/16	1 7/8	2	1 1/16	1	20	1/2	5/16	1 7/16	5/32	0.3750	0.3740	0.190	0.3760	0.3750	2 1/4	1
1 1/2	1.501	1.499	1.497	1.495	2 1/16	1 7/8	2	1 1/16	1	20	1/2	5/16	1 7/16	5/32	0.3750	0.3740	0.190	0.3760	0.3750	2 1/2	1
1 5/8	1.626	1.624	1.622	1.620	2 13/16	2 1/8	2 1/4	1 3/16	1 1/4	18	5/8	7/16	2 3/16	5/32	0.4375	0.4365	0.221	0.4385	0.4375	2 3/4	1 1/4
1 3/4	1.751	1.749	1.747	1.745	2 13/16	2 1/8	2 1/4	1 3/16	1 1/4	18	5/8	7/16	2 3/16	5/32	0.4375	0.4365	0.221	0.4385	0.4375	3	1 1/4
1 7/8	1.876	1.874	1.872	1.870	3 1/16	2 3/8	2 1/2	1 3/16	1 1/4	18	5/8	7/16	2 3/16	5/32	0.4375	0.4365	0.221	0.4385	0.4375	3 1/8	1 1/4
2	2.001	1.999	1.997	1.995	3 9/16	2 7/8	3	1 3/16	1 1/4	18	5/8	7/16	2 3/16	5/32	0.5000	0.4990	0.252	0.5010	0.5000	3 1/4	1 1/2
2 1/4	2.252	2.248	2.245	2.242	3 9/16	2 7/8	3	1 3/16	1 1/2	18	5/8	7/16	2 3/8	5/32	0.5625	0.5610	0.283	0.5640	0.5625	3 1/2	1 1/2
2 1/2	2.502	2.498	2.495	2.492	4 9/32	3 3/8	3 1/2	1 1/4	2	16	1	5/8	3 1/8	7/32	0.6250	0.6235	0.315	0.6265	0.6250	4	1 3/4
2 3/4	2.752	2.748	2.745	2.742	4 9/32	3 3/8	3 1/2	1 1/4	2	16	1	5/8	3 1/8	7/32	0.6875	0.6860	0.346	0.6890	0.6875	4 3/8	1 3/4
3	3.002	2.998	2.995	2.992	4 25/32	3 7/8	4	1 1/4	2	16	1	5/8	3 1/8	7/32	0.7500	0.7485	0.377	0.7515	0.7500	4 3/4	2
3 1/4	3.252	3.248	3.245	3.242	5 1/32	4 1/8	4 1/4	1 1/4	2	16	1	5/8	3 1/8	7/32	0.7500	0.7485	0.377	0.7515	0.7500	5	2 1/8
3 1/2	3.502	3.498	3.495	3.492	5 7/16	4 3/8	4 1/2	1 3/8	2 1/2	16	1 1/8	3/4	3 7/8	9/32	0.8750	0.8735	0.440	0.8765	0.8750	5 1/2	2 1/4
4	4.002	3.998	3.995	3.992	6 7/16	5 3/8	5 1/2	1 3/8	2 1/2	16	1 1/8	3/4	3 7/8	9/32	1.0000	0.9985	0.502	1.0015	1.0000	6 1/4	2 3/4

[a] Tolerance for ground finish, nominal +0.003, −0.002; and when specified, the maximum eccentricity with respect to the hole shall be 0.002 (indicator reading 0.004). Tolerance for lathe finish, nominal +1/32, −0.

Woodruff Keys

SAE Standard

Report of Parts and Fittings Division approved February 1928 and last revised by Parts and Fittings Technical Committee January 1951.

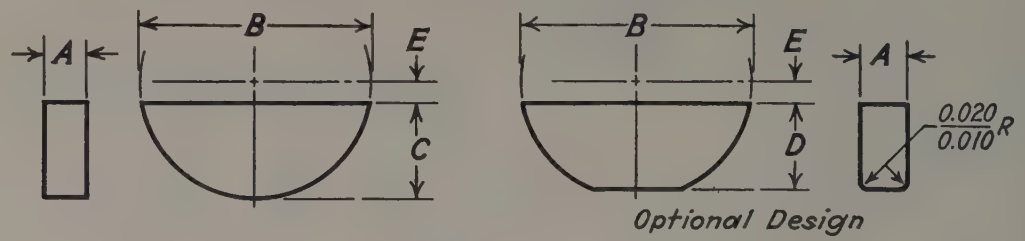


TABLE 1a—*Key Dimensions*

MFRS PART NO.	SAE NOMINAL SIZE	WIDTH, A	DIAMETER, B	HEIGHTS			KEY AREA AT SHEAR LINE	APPROXIMATE WEIGHT, LB PER 1000
				C	D	E		
		+0.001 −0.000	+0.000 −0.010	+0.000 −0.005	+0.000 −0.006	Nominal		
201	1/16 x 1/4	0.0625	0.250	0.109	—	1/64	0.0145	0.6
206	1/16 x 5/16	0.0625	0.312	0.140	—	1/64	0.0184	0.7
207	3/32 x 5/16	0.0938	0.312	0.140	—	1/64	0.0264	0.9
211	1/16 x 3/8	0.0625	0.375	0.172	—	1/64	0.0225	0.9
212	3/32 x 3/8	0.0938	0.375	0.172	—	1/64	0.0328	1.3
213	1/8 x 3/8	0.1250	0.375	0.172	—	1/64	0.0420	1.5
1	1/16 x 1/2	0.0625	0.500	0.203	0.194	3/64	0.0296	1.3
2	3/32 x 1/2	0.0938	0.500	0.203	0.194	3/64	0.0434	1.9
3	1/8 x 1/2	0.1250	0.500	0.203	0.194	3/64	0.0512	2.5
4	3/32 x 5/8	0.0938	0.625	0.250	0.240	1/16	0.0523	3.0
5	1/8 x 5/8	0.1250	0.625	0.250	0.240	1/16	0.0716	3.9
6	5/32 x 5/8	0.1563	0.625	0.250	0.240	1/16	0.0871	4.9
61	3/16 x 5/8	0.1875	0.625	0.250	0.240	1/16	0.0105	5.8
7	1/8 x 3/4	0.1250	0.750	0.313	0.303	1/16	0.0884	6.1
8	5/32 x 3/4	0.1563	0.750	0.313	0.303	1/16	0.1086	7.5
9	3/16 x 3/4	0.1875	0.750	0.313	0.303	1/16	0.1279	9.0
91	1/4 x 3/4	0.2500	0.750	0.313	0.303	1/16	0.1623	12.0
10	5/32 x 7/8	0.1563	0.875	0.375	0.365	1/16	0.1294	11.0
11	3/16 x 7/8	0.1875	0.875	0.375	0.365	1/16	0.1531	13.0
12	7/32 x 7/8	0.2188	0.875	0.375	0.365	1/16	0.1813	14.9
A	1/4 x 7/8	0.2500	0.875	0.375	0.365	1/16	0.1976	17.0
13	3/16 x 1	0.1875	1.000	0.438	0.428	1/16	0.1781	17.0
14	7/32 x 1	0.2188	1.000	0.438	0.428	1/16	0.2100	20.1
15	1/4 x 1	0.2500	1.000	0.438	0.428	1/16	0.2320	23.0
B	5/16 x 1	0.3125	1.000	0.438	0.428	1/16	0.2811	29.0
16	3/16 x 1 1/8	0.1875	1.125	0.484	0.475	5/64	0.2007	22.0
17	7/32 x 1 1/8	0.2188	1.125	0.484	0.475	5/64	0.2320	25.0
18	1/4 x 1 1/8	0.2500	1.125	0.484	0.475	5/64	0.2622	29.0
C	5/16 x 1 1/8	0.3125	1.125	0.484	0.475	5/64	0.3193	36.0
19	3/16 x 1 1/4	0.1875	1.250	0.547	0.537	5/64	0.2284	27.1
20	7/32 x 1 1/4	0.2188	1.250	0.547	0.537	5/64	0.2608	31.8
21	1/4 x 1 1/4	0.2500	1.250	0.547	0.537	5/64	0.2955	36.0
D	5/16 x 1 1/4	0.3125	1.250	0.547	0.537	5/64	0.3621	45.0
E	3/8 x 1 1/4	0.3750	1.250	0.547	0.537	5/64	0.4243	54.0
22	1/4 x 1 3/8	0.2500	1.375	0.594	0.584	3/32	0.3259	43.0
23	5/16 x 1 3/8	0.3125	1.375	0.594	0.584	3/32	0.4003	54.0
F	3/8 x 1 3/8	0.3750	1.375	0.594	0.584	3/32	0.4705	65.0
24	1/4 x 1 1/2	0.2500	1.500	0.641	0.631	7/64	0.3562	50.0
25	5/16 x 1 1/2	0.3125	1.500	0.641	0.631	7/64	0.4384	63.0
G	3/8 x 1 1/2	0.3750	1.500	0.641	0.631	7/64	0.5166	75.0

Material—Keys are to be carbon steel or alloy heat-treated steel as specified. Carbon-steel keys are to be 0.30 carbon minimum, with hardness of Rockwell C10 minimum. Alloy-steel keys are to be SAE 2330 or 8630 steel, heat-treated to a hardness of Rockwell C40–C50; or other alloy steels having equal physical properties at the same hardness. Alloy heat-treated keys are to be marked with depressions on the top to distinguish them from carbon-steel keys.

Dimensions—Dimensions are to be as given in Tables 1a, 1b, 2a, and 2b.

Width A (shown in illustrations accompanying tables)—Values

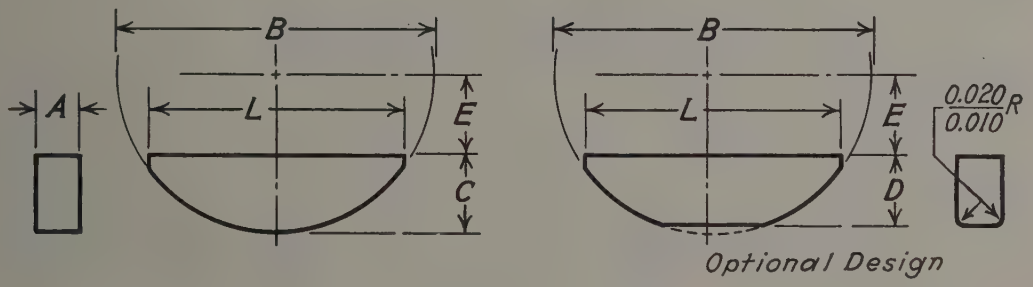
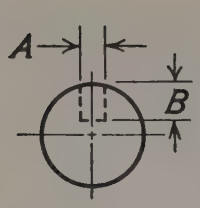
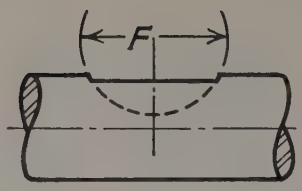


TABLE 1b—*Key Dimensions*

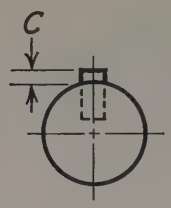
MFRS PART NO.	SAE NOMINAL SIZE	WIDTH, *A*	DIAMETER, *B*	HEIGHTS			LENGTH, *L*	KEY AREA AT SHEAR LINE	APPROXIMATE WEIGHT, LB PER 1000
				C	*D*	*E*			
		+0.001 −0.000	+0.000 −0.010	+0.000 −0.005	+0.000 −0.006	Nominal	+0.000 −0.010		
126	3/16 x 2 1/8	0.1875	2.125	0.406	0.396	21/32	1.380	0.2578	23.4
127	1/4 x 2 1/8	0.2500	2.125	0.406	0.396	21/32	1.380	0.3437	31.2
128	5/16 x 2 1/8	0.3125	2.125	0.406	0.396	21/32	1.380	0.4296	39.3
129	3/8 x 2 1/8	0.3750	2.125	0.406	0.396	21/32	1.380	0.4833	47.2
26	3/16 x 2 1/8	0.1875	2.125	0.531	0.521	17/32	1.723	0.3222	36.3
27	1/4 x 2 1/8	0.2500	2.125	0.531	0.521	17/32	1.723	0.4178	48.2
28	5/16 x 2 1/8	0.3125	2.125	0.531	0.521	17/32	1.723	0.5062	60.1
29	3/8 x 2 1/8	0.3750	2.125	0.531	0.521	17/32	1.723	0.5868	72.3
Rx	1/4 x 2 3/4	0.2500	2.750	0.594	0.584	25/32	2.000	0.5000	64.8
Sx	5/16 x 2 3/4	0.3125	2.750	0.594	0.584	25/32	2.000	0.6286	80.8
Tx	3/8 x 2 3/4	0.3750	2.750	0.594	0.584	25/32	2.000	0.6943	96.6
Ux	7/16 x 2 3/4	0.4375	2.750	0.594	0.584	25/32	2.000	0.8253	112.9
Vx	1/2 x 2 3/4	0.5000	2.750	0.594	0.584	25/32	2.000	0.9094	129.3
R	1/4 x 2 3/4	0.2500	2.750	0.750	0.740	5/8	2.317	0.5718	91.6
S	5/16 x 2 3/4	0.3125	2.750	0.750	0.740	5/8	2.317	0.7071	114.2
T	3/8 x 2 3/4	0.3750	2.750	0.750	0.740	5/8	2.317	0.8319	136.6
U	7/16 x 2 3/4	0.4375	2.750	0.750	0.740	5/8	2.317	0.9499	159.2
V	1/2 x 2 3/4	0.5000	2.750	0.750	0.740	5/8	2.317	1.0606	191.8
30	3/8 x 3 1/2	0.3750	3.500	0.938	0.927	13/16	2.880	1.0781	216.0
31	7/16 x 3 1/2	0.4375	3.500	0.938	0.927	13/16	2.880	1.2371	252.0
32	1/2 x 3 1/2	0.5000	3.500	0.938	0.927	13/16	2.880	1.3905	288.0
33	9/16 x 3 1/2	0.5625	3.500	0.938	0.927	13/16	2.880	1.5368	325.0
34	5/8 x 3 1/2	0.6250	3.500	0.938	0.927	13/16	2.880	1.6755	359.0
35	11/16 x 3 1/2	0.6875	3.500	0.938	0.927	13/16	2.880	1.8062	399.0
36	3/4 x 3 1/2	0.7500	3.500	0.938	0.927	13/16	2.880	1.9281	435.0

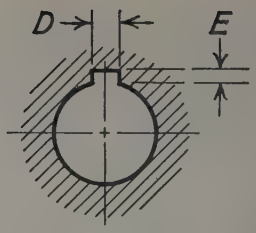


Key slot



Key above Shaft





Keyway

TABLE 2a—*Key-Slot and Keyway Dimensions*

MFRS PART NO.	SAE NOMINAL SIZE	KEY SLOT					KEY ABOVE SHAFT	KEYWAY	
		Width, *A*		Depth, *B*	Diameter, *F*		Height, *C*	Width, *D*	Depth, *E*
		Min	Max	+0.005 −0.000	Min	Max	±0.005	+0.002 −0.000	+0.005 −0.000
201	1/16 x 1/4	0.0615	0.0630	0.0728	0.255	0.263	0.0312	0.0635	0.0372
206	1/16 x 5/16	0.0615	0.0630	0.1038	0.317	0.325	0.0312	0.0635	0.0372
207	3/32 x 5/16	0.0928	0.0943	0.0882	0.317	0.325	0.0469	0.0948	0.0529
211	1/16 x 3/8	0.0615	0.0630	0.1358	0.380	0.388	0.0312	0.0635	0.0372
212	3/32 x 3/8	0.0928	0.0943	0.1202	0.380	0.388	0.0469	0.0948	0.0529
213	1/8 x 3/8	0.1240	0.1255	0.1045	0.380	0.388	0.0625	0.1260	0.0685
1	1/16 x 1/2	0.0615	0.0630	0.1668	0.510	0.518	0.0312	0.0635	0.0372
2	3/32 x 1/2	0.0928	0.0943	0.1511	0.510	0.518	0.0469	0.0948	0.0529
3	1/8 x 1/2	0.1240	0.1255	0.1355	0.510	0.518	0.0625	0.1260	0.0685
4	3/32 x 5/8	0.0928	0.0943	0.1981	0.635	0.643	0.0469	0.0948	0.0529
5	1/8 x 5/8	0.1240	0.1255	0.1825	0.635	0.643	0.0625	0.1260	0.0685
6	5/32 x 5/8	0.1553	0.1568	0.1669	0.635	0.643	0.0781	0.1573	0.0841
61	3/16 x 5/8	0.1863	0.1880	0.1513	0.635	0.643	0.0937	0.1885	0.0997
7	1/8 x 3/4	0.1240	0.1255	0.2455	0.760	0.768	0.0625	0.1260	0.0685
8	5/32 x 3/4	0.1553	0.1568	0.2299	0.760	0.768	0.0781	0.1573	0.0841
9	3/16 x 3/4	0.1863	0.1880	0.2143	0.760	0.768	0.0937	0.1885	0.0997
91	1/4 x 3/4	0.2487	0.2505	0.1830	0.760	0.768	0.1250	0.2510	0.1310
10	5/32 x 7/8	0.1553	0.1568	0.2919	0.887	0.895	0.0781	0.1573	0.0841
11	3/16 x 7/8	0.1863	0.1880	0.2763	0.887	0.895	0.0937	0.1885	0.0997
12	7/32 x 7/8	0.2175	0.2193	0.2607	0.887	0.895	0.1093	0.2198	0.1153
A	1/4 x 7/8	0.2487	0.2505	0.2450	0.887	0.895	0.1250	0.2510	0.1310
13	3/16 x 1	0.1863	0.1880	0.3393	1.012	1.020	0.0937	0.1885	0.0997
14	7/32 x 1	0.2175	0.2193	0.3237	1.012	1.020	0.1093	0.2198	0.1153
15	1/4 x 1	0.2487	0.2505	0.3080	1.012	1.020	0.1250	0.2510	0.1310
B	5/16 x 1	0.3111	0.3130	0.2768	1.012	1.020	0.1562	0.3135	0.1622
16	3/16 x 1 1/8	0.1863	0.1880	0.3853	1.137	1.145	0.0937	0.1885	0.0997
17	7/32 x 1 1/8	0.2175	0.2193	0.3697	1.137	1.145	0.1093	0.2198	0.1153
18	1/4 x 1 1/8	0.2487	0.2505	0.3540	1.137	1.145	0.1250	0.2510	0.1310
C	5/16 x 1 1/8	0.3111	0.3130	0.3228	1.137	1.145	0.1562	0.3135	0.1622
19	3/16 x 1 1/4	0.1863	0.1880	0.4483	1.265	1.273	0.0937	0.1885	0.0997
20	7/32 x 1 1/4	0.2175	0.2193	0.4327	1.265	1.273	0.1093	0.2198	0.1153
21	1/4 x 1 1/4	0.2487	0.2505	0.4170	1.265	1.273	0.1250	0.2510	0.1310
D	5/16 x 1 1/4	0.3111	0.3130	0.3858	1.265	1.273	0.1562	0.3135	0.1622
E	3/8 x 1 1/4	0.3735	0.3755	0.3545	1.265	1.273	0.1875	0.3760	0.1935
22	1/4 x 1 3/8	0.2487	0.2505	0.4640	1.390	1.398	0.1250	0.2510	0.1310
23	5/16 x 1 3/8	0.3111	0.3130	0.4328	1.390	1.398	0.1562	0.3135	0.1622
F	3/8 x 1 3/8	0.3735	0.3755	0.4015	1.390	1.398	0.1875	0.3760	0.1935
24	1/4 x 1 1/2	0.2487	0.2505	0.5110	1.515	1.523	0.1250	0.2510	0.1310
25	5/16 x 1 1/2	0.3111	0.3130	0.4798	1.515	1.523	0.1562	0.3135	0.1622
G	3/8 x 1 1/2	0.3735	0.3755	0.4485	1.515	1.523	0.1875	0.3760	0.1935

TABLE 2b—*Key-Slot and Keyway Dimensions*

MFRS PART NO.	SAE NOMINAL SIZE	KEY SLOT					KEY ABOVE SHAFT	KEYWAY	
		Width, *A*		Depth, *B*	Diameter, *F*		Height, *C*	Width, *D*	Depth, *E*
		Min	Max	+0.005 −0.000	Min	Max	±0.005	+0.002 −0.000	+0.005 −0.000
126	3/16 x 2 1/8	0.1863	0.1880	0.3073	2.125	2.140	0.0937	0.1885	0.0997
127	1/4 x 2 1/8	0.2487	0.2505	0.2760	2.125	2.140	0.1250	0.2510	0.1310
128	5/16 x 2 1/8	0.3111	0.3130	0.2448	2.125	2.140	0.1562	0.3135	0.1622
129	3/8 x 2 1/8	0.3735	0.3755	0.2135	2.125	2.140	0.1875	0.3760	0.1935
26	3/16 x 2 1/8	0.1863	0.1880	0.4323	2.125	2.140	0.0937	0.1885	0.0997
27	1/4 x 2 1/8	0.2487	0.2505	0.4010	2.125	2.140	0.1250	0.2510	0.1310
28	5/16 x 2 1/8	0.3111	0.3130	0.3698	2.125	2.140	0.1562	0.3135	0.1622
29	3/8 x 2 1/8	0.3735	0.3755	0.3385	2.125	2.140	0.1875	0.3760	0.1935
Rx	1/4 x 2 3/4	0.2487	0.2505	0.4640	2.750	2.765	0.1250	0.2510	0.1310
Sx	5/16 x 2 3/4	0.3111	0.3130	0.4328	2.750	2.765	0.1562	0.3135	0.1622
Tx	3/8 x 2 3/4	0.3735	0.3755	0.4015	2.750	2.765	0.1875	0.3760	0.1935
Ux	7/16 x 2 3/4	0.4360	0.4380	0.3703	2.750	2.765	0.2187	0.4385	0.2247
Vx	1/2 x 2 3/4	0.4985	0.5005	0.3390	2.750	2.765	0.2500	0.5010	0.2560
R	1/4 x 2 3/4	0.2487	0.2505	0.6200	2.750	2.765	0.1250	0.2510	0.1310
S	5/16 x 2 3/4	0.3111	0.3130	0.5888	2.750	2.765	0.1562	0.3135	0.1622
T	3/8 x 2 3/4	0.3735	0.3755	0.5575	2.750	2.765	0.1875	0.3760	0.1935
U	7/16 x 2 3/4	0.4360	0.4380	0.5263	2.750	2.765	0.2187	0.4385	0.2247
V	1/2 x 2 3/4	0.4985	0.5005	0.4950	2.750	2.765	0.2500	0.5010	0.2560
30	3/8 x 3 1/2	0.3735	0.3755	0.7455	3.500	3.515	0.1875	0.3760	0.1935
31	7/16 x 3 1/2	0.4360	0.4380	0.7143	3.500	3.515	0.2187	0.4385	0.2247
32	1/2 x 3 1/2	0.4985	0.5005	0.6830	3.500	3.515	0.2500	0.5010	0.2560
33	9/16 x 3 1/2	0.5610	0.5630	0.6518	3.500	3.515	0.2812	0.5635	0.2872
34	5/8 x 3 1/2	0.6235	0.6255	0.6205	3.500	3.515	0.3125	0.6260	0.3185
35	11/16 x 3 1/2	0.6860	0.6880	0.5893	3.500	3.515	0.3437	0.6885	0.3497
36	3/4 x 3 1/2	0.7485	0.7505	0.5580	3.500	3.515	0.3750	0.7510	0.3810

shown were set with the maximum key-slot width as that figure which will receive a key with the greatest amount of looseness consistent with assuring the key's sticking in the slot. Minimum key-slot width is that figure permitting the largest shaft distortion acceptable when assembling maximum key in minimum key slot.

Dimensions A, B, C, and E—These dimensions are to be taken at the side intersection.

Woodruff Key Slots and Keyways

SAE General Information

Report of Parts and Fittings Division approved February 1928 and last revised by Parts and Fittings Technical Committee January 1949.

Shaft Diameter, *L*—Decimal equivalents are given to four places in Table 1. All figures are calculated from this basic dimension. Any change in the shaft diameter from basic will necessarily change all other figures; and, in this case, should accurate dimensions be required, the formula given below should be used.

Versed Sine, *G*—The versed sines specified are determined from the following formula:

$$G = \frac{L}{2} - \sqrt{\frac{L^2 - A^2}{4}}$$

where *A* is the minimum width of the key.

Bottom of Key Slot to Opposite Side of Shaft, *H*—Obtain by

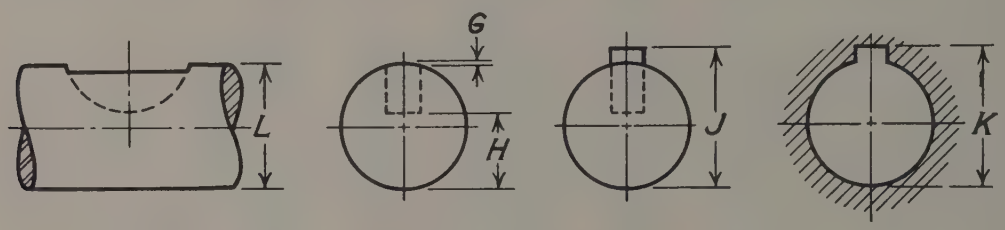


TABLE 1—*Versed Sine Dimension, G*[a]

SHAFT DIAMETER, *L*	KEYWAY WIDTH														
	1/16	3/32	1/8	5/32	3/16	7/32	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4
0.3125	0.0032	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.3437	0.0029	0.0065	—	—	—	—	—	—	—	—	—	—	—	—	—
0.3750	0.0026	0.0060	0.0107	—	—	—	—	—	—	—	—	—	—	—	—
0.4060	0.0024	0.0055	0.0099	—	—	—	—	—	—	—	—	—	—	—	—
0.4375	0.0022	0.0051	0.0091	—	—	—	—	—	—	—	—	—	—	—	—
0.4687	0.0021	0.0047	0.0085	0.0134	—	—	—	—	—	—	—	—	—	—	—
0.5000	0.0020	0.0044	0.0079	0.0125	—	—	—	—	—	—	—	—	—	—	—
0.5625	—	0.0039	0.0070	0.0111	0.0161	—	—	—	—	—	—	—	—	—	—
0.6250	—	0.0035	0.0063	0.0099	0.0144	0.0198	—	—	—	—	—	—	—	—	—
0.6875	—	0.0032	0.0057	0.0090	0.0130	0.0179	0.0235	—	—	—	—	—	—	—	—
0.7500	—	0.0029	0.0052	0.0082	0.0119	0.0163	0.0214	0.0341	—	—	—	—	—	—	—
0.8125	—	0.0027	0.0048	0.0076	0.0110	0.0150	0.0197	0.0312	—	—	—	—	—	—	—
0.8750	—	0.0025	0.0045	0.0070	0.0102	0.0139	0.0182	0.0288	—	—	—	—	—	—	—
0.9375	—	—	0.0042	0.0066	0.0095	0.0129	0.0170	0.0268	0.0391	—	—	—	—	—	—
1.0000	—	—	0.0039	0.0061	0.0089	0.0121	0.0159	0.0250	0.0365	—	—	—	—	—	—
1.0625	—	—	0.0037	0.0058	0.0083	0.0114	0.0149	0.0235	0.0342	—	—	—	—	—	—
1.1250	—	—	0.0035	0.0055	0.0079	0.0107	0.0141	0.0221	0.0322	0.0443	—	—	—	—	—
1.1875	—	—	0.0033	0.0052	0.0074	0.0102	0.0133	0.0209	0.0304	0.0418	—	—	—	—	—
1.2500	—	—	0.0031	0.0049	0.0071	0.0097	0.0126	0.0198	0.0288	0.0395	—	—	—	—	—
1.3750	—	—	—	0.0045	0.0064	0.0088	0.0115	0.0180	0.0261	0.0357	0.0471	—	—	—	—
1.5000	—	—	—	0.0041	0.0059	0.0080	0.0105	0.0165	0.0238	0.0326	0.0429	—	—	—	—
1.6250	—	—	—	0.0038	0.0054	0.0074	0.0097	0.0152	0.0219	0.0300	0.0394	0.0502	—	—	—
1.7500	—	—	—	—	0.0050	0.0069	0.0090	0.0141	0.0203	0.0278	0.0365	0.0464	—	—	—
1.8750	—	—	—	—	0.0047	0.0064	0.0084	0.0131	0.0189	0.0259	0.0340	0.0432	0.0536	—	—
2.0000	—	—	—	—	0.0044	0.0060	0.0078	0.0123	0.0177	0.0242	0.0318	0.0404	0.0501	—	—
2.1250	—	—	—	—	—	0.0056	0.0074	0.0116	0.0167	0.0228	0.0298	0.0379	0.0470	0.0572	0.0684
2.2500	—	—	—	—	—	—	0.0070	0.0109	0.0157	0.0215	0.0281	0.0357	0.0443	0.0538	0.0643
2.3750	—	—	—	—	—	—	—	0.0103	0.0149	0.0203	0.0266	0.0338	0.0419	0.0509	0.0608
2.5000	—	—	—	—	—	—	—	—	0.0141	0.0193	0.0253	0.0321	0.0397	0.0482	0.0576
2.6250	—	—	—	—	—	—	—	—	0.0135	0.0184	0.0240	0.0305	0.0377	0.0457	0.0547
2.7500	—	—	—	—	—	—	—	—	—	0.0175	0.0229	0.0291	0.0360	0.0437	0.0521
2.8750	—	—	—	—	—	—	—	—	—	0.0168	0.0219	0.0278	0.0344	0.0417	0.0498
3.0000	—	—	—	—	—	—	—	—	—	—	0.0210	0.0266	0.0329	0.0399	0.0476

[a] Listed for the different shaft sizes and keyway widths for reference in checking dimensions *H*, *J*, and *K*.

subtracting the versed sine, G, and depth of key slot, B, from the shaft diameter L.

Top of Key to Opposite Side of Shaft, J—Obtain by subtracting the versed sine, G, from the shaft diameter, L, and then adding to this figure the height of key above shaft, C.

Bottom of Keyway to Opposite Side of Bore, K—Obtain by subtracting the versed sine, G, from the shaft diameter, L, and then adding to this figure the depth of keyway, E.

Ball- and Roller-Bearing Lock Nuts and Washers

SAE Standard

Report of Ball and Roller Bearings Division approved January 1931 and last revised by Ball and Roller Bearings Technical Committee January 1950.

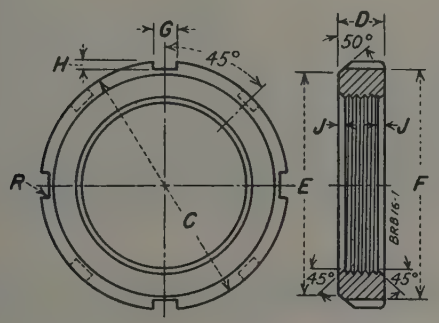


FIG. 1—BALL- AND ROLLER-BEARING LOCK NUTS

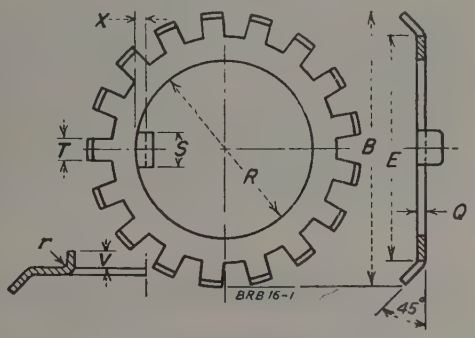


FIG. 4—BALL- AND ROLLER-BEARING LOCK WASHERS

Runout and parallelism of faces, measured mounted on a tight-fitting threaded arbor:

N00 to N06 = 0.002 in. maximum
N07 to AN22 = 0.004 in. maximum
AN24 to AN40 = 0.006 in. maximum
8N00 to 8AN140 = 0.002 in. maximum

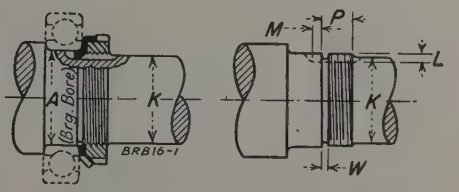
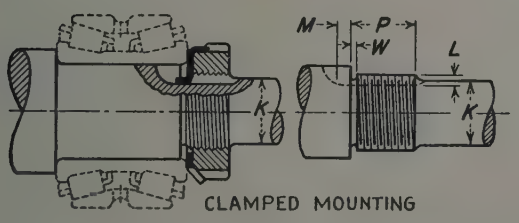


FIG. 2—SHAFTS FOR BALL-BEARING LOCK NUTS



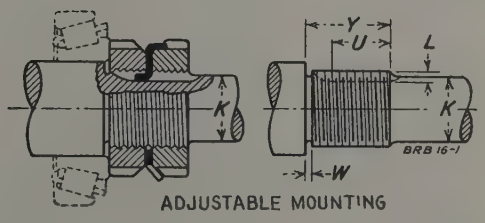


FIG. 3—SHAFTS FOR TAPER ROLLER-BEARING LOCK NUTS

(*Continued on next page.*)

TABLE 1—LOCK NUTS FOR BALL AND ROLLER BEARINGS (FIG. 1)

Ball; Cylindrical and Spherical Roller Bearings 4 Slots			Taper Roller Bearings 8 Slots			Outside Diam. C	Face Diam. E		Ctsk. Depth	Slot Dimensions				
										Diam. F	Width G		Height H	Fillet R
SAE No.	Thick. D		SAE No.	Thick. D		+.005 −.015	Min.	Max.	J	+.010 −.020	Min.	Max.	±.010	
	Min.	Max.		Min.	Max.									
N-00	0.209	0.229	8-N-00	0.209	0.229	3/4	0.605	0.625	1/32	5/8	.120	.130	1/16	.010
N-01	0.303	0.323	8-N-01	0.303	0.323	7/8	0.699	0.719	1/32	3/4	.120	.130	1/16	.010
N-02	0.303	0.323	8-N-02	0.303	0.323	1	0.793	0.813	1/32	13/16	.120	.130	3/32	.010
N-03	0.334	0.354	8-N-03	0.334	0.354	1 1/8	0.918	0.938	1/32	15/16	.120	.130	3/32	.010
N-04	0.365	0.385	8-N-04	0.365	0.385	1 3/8	1.105	1.125	1/32	1 3/16	.178	.198	3/32	.015
N-05	0.396	0.416	8-N-05	0.396	0.416	1 5/16	1.261	1.281	1/32	1 3/8	.178	.198	3/32	.015
N-06	0.396	0.416	8-N-06	0.396	0.416	1 3/4	1.480	1.500	1/64	1 5/16	.178	.198	3/32	.015
....	....	....	8-N-065	0.428	0.448	2 1/16	1.793	1.813	1/64	1 7/8	.178	.198	3/32	.015
N-07	0.428	0.448	8-N-07	0.428	0.448	2 1/16	1.793	1.813	1/64	1 7/8	.178	.198	3/32	.015
N-08	0.428	0.448	8-N-08	0.428	0.448	2 1/4	1.980	2.000	1/64	2 1/16	.240	.260	3/32	.020
N-09	0.428	0.448	8-N-09	0.428	0.448	2 17/32	2.261	2.281	1/64	2 1/32	.240	.260	3/32	.020
N-10	0.490	0.510	8-N-10	0.490	0.510	2 17/32	2.418	2.438	1/64	2 1/2	.240	.260	3/32	.020
N-11	0.490	0.510	8-N-11	0.490	0.510	2 31/32	2.636	2.656	1/64	2 23/32	.240	.260	1/8	.020
N-12	0.521	0.541	8-N-12	0.521	0.541	3 1/32	2.824	2.844	1/64	2 25/32	.240	.260	1/8	.020
N-13	0.553	0.573	8-N-13	0.553	0.573	3 3/8	3.043	3.063	1/64	3 1/8	.240	.260	1/8	.020
N-14	0.553	0.573	8-N-14	0.553	0.573	3 5/8	3.283	3.313	1/64	3 3/8	.240	.260	1/8	.020
AN-15	0.584	0.604	8-AN-15	0.584	0.604	3 7/8	3.533	3.563	1/64	3 5/8	.360	.385	1/8	025
AN-16	0.584	0.604	8-AN-16	0.584	0.604	4 1/32	3.814	3.844	1/64	3 29/32	.360	.385	1/8	.025
AN-17	0.615	0.635	8-AN-17	0.615	0.635	4 13/32	4.001	4.031	1/64	4 3/32	.360	.385	5/32	.025
AN-18	0.678	0.698	8-AN-18	0.678	0.698	4 17/32	4.251	4.281	1/64	4 1/32	.360	.385	5/32	.025
AN-19	0.709	0.729	8-AN-19	0.709	0.729	4 33/64	4.533	4.563	1/64	4 5/8	.360	.385	5/32	.025
AN-20	0.735	0.760	8-AN-20	0.735	0.760	5 1/16	4.783	4.813	1/64	4 7/8	.360	.385	5/32	.025
AN-21	0.735	0.760	8-AN-21	0.735	0.760	5 1/16	4.970	5.000	1/64	5 1/16	.485	.510	1/16	.030
AN-22	0.766	0.791	8-AN-22	0.766	0.791	5 13/32	5.251	5.281	1/64	5 11/32	.485	.510	3/16	.030
AN-24	0.798	0.823	8-AN-24	0.798	0.823	6 1/8	5.658	5.688	1/64	5 3/4	.485	.510	3/16	.030
AN-26	0.860	0.885	8-AN-26	0.860	0.885	6 3/4	6.158	6.188	1/64	6 1/4	.610	.635	1/4	.030
AN-28	0.923	0.948	8-AN-128	1.173	1.198	7 3/32	6.501	6.531	1/64	6 19/32	.610	.635	1/4	.030
AN-30	0.954	0.979	8-AN-130	1.235	1.260	7 11/16	7.033	7.063	1/64	7 1/8	.610	.635	1/32	.030
AN-32	1.016	1.041	8-AN-132	1.266	1.291	8 1/16	7.398	7.438	1/32	7 1/2	.610	.635	1/32	.030
AN-34	1.048	1.073	8-AN-134	1.329	1.354	8 21/32	7.991	8.031	1/32	8 1/32	.610	.635	1/32	.030
AN-36	1.079	1.104	8-AN-136	1.391	1.416	9 1/16	8.335	8.375	1/32	8 7/16	.735	.760	5/16	.030
AN-38	1.110	1.135	8-AN-138	1.391	1.416	9 13/32	8.741	8.781	1/32	8 51/64	.735	.760	5/16	.030
AN-40	1.173	1.198	8-AN-140	1.485	1.510	9 13/32	9.116	9.156	1/32	9 1/32	.735	.760	5/16	.030

TABLE 2—THREADS FOR BALL AND ROLLER BEARING LOCK NUTS AND SHAFTS

SAE No.	SAE No.	Thds. per Inch	Lock Nut Threads (Fig. 1)							Shaft Threads (Figs. 2 and 3)						
			Minor Diam.			Pitch Diam.			Major Diam. Min.	Major Diam.			Pitch Diam.			Minor Diam. Max.
			Min.	Tol.	Max.	Min.	Tol.	Max.		Max.	Tol.	Min.	Max.	Tol.	Min.	
N-00	8-N-00	32	0.3572	.0034	0.3606	0.3707	.0026	0.3733	0.391	0.391	.0054	0.3836	0.3707	.0026	0.3681	0.3527
N-01	8-N-01	32	0.4352	.0034	0.4386	0.4487	.0026	0.4513	0.469	0.469	.0054	0.4636	0.4487	.0026	0.4461	0.4307
N-02	8-N-02	32	0.5522	.0034	0.5556	0.5657	.0030	0.5687	0.586	0.586	.0054	0.5806	0.5657	.0030	0.5627	0.5477
N-03	8-N-03	32	0.6302	.0034	0.6336	0.6437	.0030	0.6467	0.664	0.664	.0054	0.6586	0.6437	.0030	0.6407	0.6257
N-04	8-N-04	32	0.7472	.0034	0.7506	0.7607	.0034	0.7641	0.781	0.781	.0054	0.7756	0.7607	.0034	0.7573	0.7427
N-05	8-N-05	32	0.9352	.0034	0.9386	0.9487	.0034	0.9521	0.969	0.969	.0054	0.9636	0.9487	0034	0.9453	0.9307
N-06	8-N-06	18	1.1129	.0060	1.1189	1.1369	.0040	1.1409	1.173	1.173	.0082	1.1648	1.1369	.0040	1.1329	1.1048
....	8-N-065	18	1.2524	.0060	1.2584	1.2764	.0040	1.2804	1.3125	1.3125	.0082	1.3043	1.2764	.0040	1.2724	1.2443
N-07	8-N-07	18	1.3159	.0060	1 3219	1.3399	.0040	1.3439	1.376	1.376	.0082	1.3678	1.3399	.0040	1.3359	1.3078
N-08	8-N-08	18	1.5029	.0060	1.5089	1.5269	.0045	1 5314	1.563	1.563	.0082	1.5548	1.5269	.0045	1.5224	1.4948
N-09	8-N-09	18	1.7069	.0060	1.7129	1.7309	.0045	1.7354	1.767	1.767	.0082	1.7588	1.7309	.0045	1.7264	1.6988
N-10	8-N-10	18	1.9069	.0060	1.9129	1.9309	.0045	1.9354	1.967	1.967	.0082	1.9588	1.9309	.0045	1.9264	1.8998
N-11	8-N-11	18	2.0969	.0060	2 1029	2.1209	.0051	2.1260	2.157	2.157	.0082	2.1488	2.1209	.0051	2.1158	2.0888
N-12	8-N-12	18	2.2999	.0060	2.3059	2.3239	.0051	2.3290	2.360	2 360	.0082	2.3518	2.3239	.0051	2.3188	2 2918
N-13	8-N-13	18	2.4879	0060	2.4939	2.5119	.0051	2.5170	2.548	2.548	.0082	2.5398	2.5119	.0051	2.5068	2.4798
N-14	8-N-14	18	2.6909	.0060	2.6969	2.7149	.0051	2.7200	2.751	2.751	.0082	2.7428	2.7149	.0051	2.7098	2.6828
AN-15	8-AN-15	12	2.8428	.0090	2.8518	2.8789	.0054	2.8843	2.933	2.933	.0112	2.9218	2.8789	.0054	2.8735	2.8308
AN-16	8-AN-16	12	3.0468	.0090	3.0558	3.0829	.0059	3.0888	3.137	3.137	.0112	3.1258	3.0829	.0059	3.0770	3.0348
AN-17	8-AN-17	12	3.2498	.0090	3.2588	3.2859	.0074	3.2933	3.340	3.340	.0112	3.3288	3.2859	.0074	3.2785	3.2378
AN-18	8-AN-18	12	3.4368	.0090	3.4458	3.4729	.0074	3.4803	3.527	3.527	.0112	3.5158	3.4729	.0074	3.4655	3.4248
AN-19	8-AN-19	12	3.6398	.0090	3.6488	3.6759	.0074	3.6833	3.730	3.730	.0112	3.7188	3.6759	.0074	3.6685	3.6278
AN-20	8-AN-20	12	3.8278	.0090	3.8368	3.8639	.0074	3.8713	3.918	3.918	.0112	3.9068	3.8639	.0074	3.8565	3.8158
AN-21	8-AN-21	12	4.0318	.0090	4.0408	4.0679	.0083	4.0762	4.122	4.122	.0112	4.1108	4.0679	.0083	4.0596	4.0198
AN-22	8-AN-22	12	4.2348	.0090	4.2438	4.2709	.0083	4.2792	4.325	4.325	.0112	4.3138	4.2709	.0083	4.2626	4.2228
AN-24	8-AN-24	12	4.6258	.0090	4.6348	4.6619	.0083	4.6702	4.716	4.716	.0112	4.7048	4.6619	.0083	4.6536	4.6138
AN-26	8-AN-26	12	5.0158	.0090	5.0248	5.0519	.0083	5.0602	5.106	5.106	.0112	5.0948	5.0519	.0083	5.0436	5.0038
AN-28	8-AN-128	12	5.4068	.0090	5.4158	5.4429	.0083	5.4512	5.497	5.497	.0112	5.4858	5.4429	.0083	5.4346	5.3948
AN-30	8-AN-130	12	5.7978	.0090	5.8068	5.8339	.0083	5.8422	5.888	5.888	.0112	5.8768	5.8339	.0083	5.8256	5.7858
AN-32	8-AN-132	8	6.1487	.0135	6.1622	6.2028	.0091	6.2119	6.284	6.284	.0152	6.2688	6.2028	.0091	6.1937	6.1306
AN-34	8-AN-134	8	6.5237	.0135	6.5372	6.5778	.0091	6.5869	6.659	6.659	.0152	6.6438	6.5778	.0091	6.5687	6.5056
AN-36	8-AN-136	8	6.9307	.0135	6.9442	6.9848	.0091	6.9939	7.066	7.066	.0152	7.0508	6.9848	.0091	6.9757	6.9126
AN-38	8-AN-138	8	7.3367	.0135	7.3502	7.3908	.0091	7.3999	7.472	7.472	.0152	7.4568	7.3908	.0091	7.3817	7.3186
AN-40	8-AN-140	8	7.7117	.0135	7.7252	7.7658	.0114	7.7772	7.847	7.847	.0152	7.8318	7.7658	.0114	7.7544	7.6936

TABLE 3—SHAFTS FOR BALL AND ROLLER BEARING LOCK NUTS

Ball Bearings Cylindrical and Spherical Roller Bearings (Fig. 2)								Taper Roller Bearings (Fig. 3)								
				Keyway[1]						Thread Length[1]		Keyway[1]				
SAE No.	Bear. Bore	Diam. K Max.	Thread Length[1] P	Depth L	Width N	L'gth M	Thread Relief[1] W	SAE No.	Diam. K Max.	Y	P	Depth L	Width N	Length M	Length U	Thread Relief[1] W
N-00	0.3937	5/16	9/32	1/16	1/8	3/32	1/16	8-N-00	5/16	19/32	3/8	3/32	1/8	3/32	15/32	1/16
N-01	0.4724	13/32	3/8	1/16	1/8	3/32	1/16	8-N-01	13/32	23/32	15/32	3/32	1/8	3/32	9/16	1/16
N-02	0.5906	1/2	3/8	5/64	1/8	3/32	1/16	8-N-02	1/2	13/16	1/2	3/32	1/8	3/32	19/32	1/16
N-03	0.6693	9/16	13/32	1/64	1/8	3/32	1/16	8-N-03	9/16	7/8	17/32	3/32	1/8	3/32	5/8	1/16
N-04	0.7874	23/32	7/16	5/64	3/16	3/32	1/16	8-N-04	45/64	29/32	17/32	3/32	3/16	3/32	5/8	1/16
N-05	0.9843	7/8	15/32	3/32	3/16	1/8	1/16	8-N-05	7/8	1	19/32	1/8	3/16	1/8	23/32	1/16
N-06	1.1811	1 1/16	15/32	3/32	3/16	1/8	1/8	8-N-06	1 1/16	1	19/32	1/8	3/16	1/8	23/32	1/8
....	....	....	....	....	....	....	....	8-N-065	1 3/16	1 1/16	5/8	1/8	3/16	1/8	3/4	1/8
N-07	1.3780	1 1/4	1/2	3/32	3/16	1/8	1/8	8-N-07	1 1/4	1 1/16	5/8	1/8	3/16	1/8	3/4	1/8
N-08	1.5748	1 15/32	17/32	3/32	3/16	1/8	1/8	8-N-08	1 7/16	1 1/16	5/8	1/8	3/16	1/8	3/4	1/8
N-09	1.7717	1 11/16	17/32	3/32	5/16	5/32	1/8	8-N-09	1 21/32	1 1/16	5/8	1/8	3/16	5/32	3/4	1/8
N-10	1.9685	1 7/8	19/32	3/32	5/16	5/32	1/8	8-N-10	1 55/64	1 3/16	11/16	1/8	3/16	5/32	27/32	1/8
N-11	2.1654	2 1/16	19/32	1/8	5/16	5/32	1/8	8-N-11	2 3/64	1 3/16	11/16	1/8	5/16	5/32	27/32	1/8
N-12	2.3622	2 1/4	5/8	1/8	5/16	5/32	1/8	8-N-12	2 1/4	1 5/32	3/4	5/32	5/16	5/32	29/32	1/8
N-13	2.5591	2 7/16	21/32	1/8	5/16	5/32	1/8	8-N-13	2 27/64	1 11/32	25/32	5/32	5/16	5/32	15/16	1/8
N-14	2.7559	2 5/8	21/32	1/8	5/16	1/4	1/8	8-N-14	2 5/8	1 11/32	25/32	5/32	5/16	1/4	1	1/8
AN-15	2.9528	2 23/32	11/16	1/8	5/16	1/4	5/32	8-AN-15	2 23/32	1 13/32	13/16	3/16	5/16	1/4	1 1/32	5/32
AN-16	3.1496	3	11/16	1/8	3/8	1/4	5/32	8-AN-16	3	1 13/32	13/16	3/16	3/8	1/4	1 1/32	5/32
AN-17	3.3465	3 3/16	23/32	1/8	3/8	1/4	5/32	8-AN-17	3 3/16	1 15/32	27/32	5/16	3/8	1/4	1 1/16	5/32
AN-18	3.5433	3 3/8	13/16	5/32	3/8	1/4	5/32	8-AN-18	3 3/8	1 5/8	15/16	7/32	3/8	1/4	1 5/32	5/32
AN-19	3.7402	3 3/16	27/32	5/32	3/8	1/4	5/32	8-AN-19	3 9/16	1 11/16	31/32	7/32	3/8	1/4	1 3/16	5/32
AN-20	3.9370	3 23/32	7/8	5/32	3/8	5/16	5/32	8-AN-20	3 49/64	1 3/4	1	7/32	3/8	5/16	1 3/32	5/32
AN-21	4.1339	3 15/16	7/8	5/32	3/8	5/16	5/32	8-AN-21	3 15/16	1 3/4	1	7/32	3/8	5/16	1 3/32	5/32
AN-22	4.3307	4 3/16	29/32	3/16	3/8	5/16	5/32	8-AN-22	4 5/32	1 13/16	1 1/32	7/32	3/8	5/16	1 5/16	5/32
AN-24	4.7244	4 9/16	15/16	3/16	3/8	5/16	5/32	8-AN-24	4 17/32	1 29/32	1 3/32	1/4	3/8	5/16	1 3/8	5/32
AN-26	5.1181	4 15/16	1	7/16	1/2	5/16	5/32	8-AN-26	4 29/32	2 1/32	1 5/32	1/4	1/2	5/16	1 7/16	5/32
AN-28	5.5118	5 5/16	1 1/16	7/16	5/8	5/16	5/32	8-AN-128	5 19/64	2 1/32	1 11/32	1/4	5/8	5/16	1 3/4	5/32
AN-30	5.9055	5 23/32	1 1/8	1/2	5/8	3/8	5/32	8-AN-130	5 21/32	2 13/16	1 5/16	5/32	5/8	3/8	1 29/32	5/32
AN-32	6.2992	6 1/8	1 3/16	15/64	5/8	3/8	1/4	8-AN-132	6 1/16	2 7/8	1 15/32	5/16	5/8	3/8	1 15/16	1/4
AN-34	6.6929	6 1/2	1 7/32	15/64	3/4	3/8	1/4	8-AN-134	6 7/16	3	1 21/32	5/16	3/4	3/8	2	1/4
AN-36	7.0866	6 29/32	1 1/4	15/64	3/4	3/8	1/4	8-AN-136	6 21/32	3 1/8	1 23/32	5/16	3/4	3/8	2 1/16	1/4
AN-38	7.4803	7 5/16	1 9/32	15/64	3/4	3/8	1/4	8-AN-138	7 1/4	3 1/8	1 23/32	5/16	3/4	3/8	2 1/16	1/4
AN-40	7.8740	7 11/16	1 11/32	15/64	7/8	3/8	1/4	8-AN-140	7 5/8	3 5/16	1 13/16	5/16	7/8	3/8	2 1/8	1/4

[1] Tolerance, + 1/64, − 0

TABLE 4—LOCK WASHERS FOR BALL AND ROLLER BEARING LOCK NUTS (FIG. 4)

Stock Thickness Q				Tangs			Key						Bore R		Diameter		
					Width		Projection		Width S		Bend X						
SAE No.	Q	SAE No.	Q	No.	T	Tol. ±	V	Tol. +	Min.	Max.	Min.	Max.	Rad. r	Min.	Max.	E	Tol. +	Diam. B over Tangs Max.
W-00	.042	...	...	9	.115	.007	1/16	1/32	.110	.120	.020	.030	1/64	.406	.421	5/8	.015	7/8
W-01	.042	...	...	9	.115	.007	1/16	1/32	.110	.120	.020	.030	1/64	.484	.499	23/32	.015	1 1/64
W-02	.042	W-102	.058	11	.115	.007	1/16	1/32	.110	.120	.020	.030	1/64	.601	.616	13/16	.015	1 3/32
W-03	.042	W-103	.058	11	.115	.007	1/16	1/32	.110	.120	.020	.030	1/64	.679	.694	15/16	.015	1 21/64
W-04	.042	W-104	.058	11	.156	.010	1/16	1/32	.156	.176	.020	.030	1/64	.801	.816	1 1/8	.015	1 11/32
W-05	.050	W-105	.062	13	.156	.010	3/32	1/32	.156	.176	.020	.030	1/64	.989	1.009	1 3/32	.015	1 23/32
W-06	.050	W-106	.062	13	.156	.010	3/32	1/32	.156	.176	.035	.050	1/32	1.193	1.213	1 1/2	.015	1 53/64
...	...	W-065	.062	15	.156	.010	3/32	1/32	.156	.176	.035	.050	1/32	1.333	1.353	1 13/16	.015	2 1/4
W-07	.050	W-107	.062	15	.156	.010	3/32	1/32	.156	.176	.035	.050	1/32	1.396	1.416	1 13/16	.015	2 1/4
W-08	.058	W-108	.072	15	.219	.015	3/32	1/32	.250	.290	.035	.050	1/32	1.583	1.603	2	.030	2 15/32
W-09	.058	W-109	.072	17	.219	.015	1/8	1/32	.250	.290	.035	.050	1/32	1.792	1.817	2 3/32	.030	2 47/64
W-10	.058	W-110	.072	17	.219	.015	1/8	1/32	.250	.290	.035	.050	1/32	1.992	2.017	2 7/16	.030	2 49/64
W-11	.063	W-111	.072	17	.219	.015	1/8	1/32	.250	.290	.035	.050	1/32	2.182	2.207	2 21/32	.030	3 1/64
W-12	.063	W-112	.082	17	.219	.015	1/8	1/32	.250	.290	.055	.070	3/64	2.400	2.425	2 27/32	.030	3 11/32
W-13	.063	W-113	.082	19	.219	.015	1/8	1/32	.250	.290	.055	.070	3/64	2.588	2.613	3 1/16	.030	3 37/64
W-14	.063	W-114	.082	19	.219	.015	1/8	1/32	.250	.290	.055	.070	3/64	2.791	2.816	3 3/16	.030	3 53/64
W-15	.072	W-115	.095	19	.313	.015	3/16	1/16	.250	.290	.055	.070	3/64	2.973	3.003	3 5/16	.030	4 1/64
W-16	.072	W-116	.095	19	.313	.015	3/16	1/16	.313	.353	.055	.070	3/64	3.177	3.207	3 21/32	.030	4 3/8
W-17	.072	W-117	.095	19	.313	.015	3/16	1/16	.313	.353	.055	.070	3/64	3.395	3.425	4 1/32	.030	4 5/8
W-18	.094	W-118	.125	19	.313	.015	3/16	1/16	.313	.353	.055	.070	3/64	3.582	3.612	4 3/32	.045	4 15/16
W-19	.094	W-119	.125	19	.313	.015	3/16	1/16	.313	.353	.055	.070	3/64	3.800	3.830	4 5/16	.045	5 5/32
W-20	.094	W-120	.125	19	.313	.015	1/4	1/16	.313	.353	.065	.085	3/64	3.988	4.018	4 13/32	.045	5 1/2
W-21	.094	W-121	.125	19	.375	.015	1/4	1/16	.313	.353	.065	.085	3/64	4.192	4.222	5	.045	5 45/64
W-22	.125	W-122	.140	19	.375	.015	1/4	1/16	.313	.353	.065	.085	3/64	4.395	4.425	5 5/32	.045	6 1/16
W-24	.125	W-124	.165	19	.375	.015	1/4	1/16	.313	.353	.065	.085	3/64	4.801	4.831	5 11/16	.045	6 13/32
W-26	.125	W-126	.165	19	.500	.020	1/4	1/16	.375	.435	.085	.105	1/16	5.191	5.226	6 3/16	.045	7 1/32
W-28	.125	W-128	.165	19	.500	.020	1/4	1/16	.500	.590	.085	.105	1/16	5.582	5.617	6 1/32	.045	7 7/16
W-30	.156	W-130	.203	19	.500	.020	5/16	1/16	.500	.590	.085	.105	1/16	5.983	6.018	7 1/16	.060	8 1/16
W-32	.156	W-132	.203	19	.500	.020	5/16	1/16	.500	.590	.085	.105	1/16	6.389	6.424	7 7/16	.060	8 7/16
W-34	.156	W-134	.203	19	.500	.020	5/16	1/16	.625	.715	.085	.105	1/16	6.764	6.799	8 1/32	.060	9 1/16
W-36	.156	W-136	.203	19	.625	.020	5/16	1/16	.625	.715	.085	.105	1/16	7.171	7.206	8 3/8	.060	9 7/16
W-38	.156	W-138	.203	19	.625	.020	5/16	1/16	.625	.715	.085	.105	1/16	7.577	7.612	8 25/32	.060	9 7/8
W-40	.156	W-140	.203	19	.625	.020	5/16	1/16	.750	.840	.085	.105	1/16	7.982	8.017	9 9/32	.060	10 5/16

Antifriction Ball and Roller Bearings

SAE Standard

Report of Ball and Roller Bearings Division approved June 1911 and last revised by Ball and Roller Bearings Technical Committee January 1949.

The accompanying tables include the types, complete ranges of standard sizes, and their boundary dimensions of standard antifriction ball and roller bearings commonly used for automotive applications. Many sizes listed are commonly used to only a limited extent, and it is therefore suggested that in selecting bearings for a given application, the bearing manufacturers or their catalogs be consulted as to the more readily obtainable or the preferred sizes of bearings.

Tolerances—For applications requiring closer tolerances on the bearing dimensions than those shown in the tables of standard bearings, Tolerance Specifications ABEC 3, ABEC 5 and ABEC 7 are available for single-row radial and angular contact ball bearings types BC, BA, BN, BT, and BIC; RBEC 5 is also available for various types of roller bearings. The bearing manufacturers should be consulted for closer than standard tolerances (ABEC 1[1], RBEC 1[2]). Dimensional tables show average tolerances only. (See SAE Standard for Ball- and Roller-Bearing Tolerances for d_{min} and d_{max}, D_{min} and D_{max}). Tapered roller bearings may be obtained to five dimensional tolerance specifications as shown in Table 8 in SAE Standard for Tapered Roller Bearings.

Standard for Measurements—Because of the relatively thin ring sections existing and the possible deformation of rings that can occur under various gaging load practices, standard AFBMA[3] Gaging Methods and Loads are established to insure agreement in the measurements obtained when inspecting ball and roller bearings.

The standards used for checking gaging equipment conform with those used by the National Bureau of Standards at a temperature of 68 F. All measurements shall be made after the gaging equipment and parts to be measured have been brought to the temperature of the room in which the measurements are to be made.

When gaging dimensions of the bearings, gaging loads and dimensions of gaging points are to be as shown in Table 1.

TABLE 1—*Gaging Loads and Gaging Points*

	NOMINAL DIAM, MM	GAGE LOAD, OZ	GAGE POINT RADIUS	
			Mm	In.
Inner ring bore	Over 0 to 9 incl	Not exceeding 7	0.8	0.032
	Over 9 to 30 incl	Not exceeding 7	2.5	0.098
	30 and over	12	2.5	0.098
Outer ring OD	0 and over	Not exceeding 7	2.5	0.098

Bore—For determining bore diameter, use apparatus arranged for two-point measuring. If out-of-roundness and taper exist in a particular bearing, a minimum diameter reading d_{min} and a maximum diameter reading d_{max} may be obtained. The bore diameter d_m, of the bearing in question is defined as the arithmetical average of these two readings, d_{min} and d_{max}. Large-diameter rings with thin section should be placed in a horizontal position when measuring.

Outside Diameter—For determining the outside diameter, use apparatus arranged for measuring between a flat surface and a rounded calibrated indicator point. If out-of-roundness and taper exist in a particular bearing, a minimum diameter reading D_{min} and a maximum diameter reading D_{max} may be obtained. The outside diameter D_m of the bearing in question is defined as the arithmetical average of these two readings, D_{min} and D_{max}. When measuring thin section rings, the measuring pressure should be small so as to avoid distortion of the rings. Large-diameter rings with thin sections should be placed in a horizontal position when measuring.

Width—The tolerances for width of the bearings apply to the individual rings and not to the total width of the bearing. One ring is free and the other ring that is to be measured, is supported on one side by three buttons. Apply a calibrated indicator against the other side directly over one button, and take readings while rotating the ring.

Eccentricity—Mount the bearing on an arbor having a very slight taper (0.0001 to 0.0002 in. on diameter per in. of length). Apply a calibrated indicator on the center of the stationary outer ring. The inner-ring eccentricity is the difference between the minimum and maximum reading when rotating the arbor one revolution. The outer-ring eccentricity is the difference between the minimum and maximum reading when rotating the outer ring one revolution with the arbor stationary. Corrections should be made for the inaccuracy of the arbor.

Corner Radius and Fillets—In metric ball and roller bearings, no dimensions are established for the size or shape of the bearing

corners. Instead the maximum shaft and housing fillet radii are given that the bearing corners must clear. For tapered roller bearings, corner dimensions are given that apply to the actual contour of the bearing parts.

End Play—The bearing is to be lubricated with light oil and one of its rings clamped to prevent axial movement. The specified reversing measuring load is so applied to the unclamped ring that resultant movement of that ring is parallel to the bearing axis. The end play is the total movement of the unclamped ring when

TABLE 2—*End-Play Measuring Loads*

LOADS		FOR BEARINGS WITH BORE (MM)
Kg	Lb	
2½	5½	Over 0 to 50 incl
5	11	Over 50 to 120 incl
10	22	Over 120 to 200 incl
15	44	Over 200

[1] ABEC—Annular Bearing Engineers' Committee.
[2] RBEC—Roller Bearing Engineers' Committee.
[3] AFBMA—Antifriction Bearing Manufacturers Association.

the load is applied first in one direction and then in the other direction. See Table 2.

Conversion Factors[4]—The following factor, used for the conversions in the accompanying tables of antifriction bearings, was adopted by the Society in June 1932 and approved by the American Standards Association as the American Standard B48.1–1933 in January 1933 because of its relative simplicity and adequate accuracy for practical industrial and commercial conversions. The inaccuracy is only 2 millionths of an in. per in. 1 in. = 25.4 mm.

Where more exact scientific or very accurate industrial conversions are required, the factor 25.40005 should be used.

[4] The legal conversion in the United States, established for the international meter by act of Congress on July 28, 1866, defines one meter as equal to 39.37 in., for which the factors 25.4 mm per in. and 0.03937 in. per mm are derived as published in the National Bureau of Standards Circular No. 47, issued July 1, 1914, and supplemented October 27, 1917

The reciprocal factor 1 mm = 0.03937 in. is recommended for all usual industrial and commercial conversions. Where very accurate conversions are desired the factor 0.039370079 may be used.

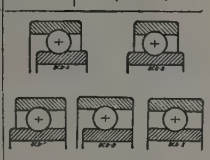
Rounding Off Numbers—When a decimal value is to be rounded off to a lesser number of places than the total number available, the procedure (American Standard 225.1 — 1940) should be as follows:

When the figure next beyond the last figure to be retained is less than 5, the last figure retained should not be changed.

When the figure next beyond the last figure to be retained is more than 5, the last figure retained should be increased by 1.

When the figure next beyond the last place to be retained is exactly 5 with only zeros beyond, the last figure retained if even, should be unchanged; if odd, it should be increased by 1.

Types of Antifriction Ball and Roller Bearings

Type	*Description*	*Table*	*Cross Section*
BA	**Ball Bearing.** Single row, angular contact, self-contained, contact angle 22 to 32 deg. incl. Metric dimensions.	2a, 2b	
BAF	**Ball Bearing.** Single row, angular contact with offset rings, developed for automobile front wheels. Metric and inch dimensions.	9	
BAK	**Ball Bearing.** Angular contact, developed for steering knuckles. Metric and inch dimensions. Consult manufacturer for dimensions.	(none)	
BC	**Ball Bearing.** Single row, radial, non-filling slot assembly. Metric dimensions.	1, 2a 2b, 3	
BCB	**Ball Bearing.** Single row, radial, non-filling slot assembly, rings adapted for integral sealing, developed for automobile rear wheels. Metric and inch dimensions.	10	
BCD	**Ball Bearing.** Single row, radial, non-filling slot assembly, rings adapted for integral sealing. Metric and inch dimensions. Consult manufacturer for dimensions. (No tables for these bearings.)		
BN	**Ball Bearing.** Single row, angular contact, self-contained, contact angle less than 22 deg. Metric dimensions.	1, 2a, 2b	
BL	**Ball Bearing.** Single row, radial, filling slot assembly. Metric dimensions.	2a, 2b 3	
BT	**Ball Bearing.** Single row, angular contact, self-contained, contact angle larger than 32 but less than 45 deg. Metric dimensions.	2a, 2b	
BM	**Ball Bearing.** Single row, separable assembly. Metric dimensions.	6	

Type	*Description*	*Table*	*Cross Section*
BD	**Ball Bearing.** Double row, filling slot assembly, angular contact, vertex of contact angle inside bearing. Metric dimensions.	7	
BE	**Ball Bearing.** Double row, filling slot assembly, angular contact, vertex of contact angle outside bearing. Metric dimensions.	7	
BF	**Ball Bearing.** Double row, filling slot assembly, radial contact. Metric dimensions.	7	
BG	**Ball Bearing.** Double row, non-filling slot assembly, angular contact, vertex of contact angle outside bearing. Metric dimensions.	7	
BIC	**Ball Bearing.** Single row, radial, non-filling slot assembly. Inch dimensions.	5	
BJ	**Ball Bearing.** Double row, non-filling slot assembly, angular contact, vertex of contact angle inside bearing. Metric dimensions.	7	
BK	**Ball Bearing.** Double row, non-filling slot assembly, radial contact. Metric dimensions.	7	
BRT	**Roller Tooth Bearings.** Developed for steering post. Metric and inch dimensions. Consult manufacturer for dimensions.	(none)	
BS	**Ball Bearing.** Double row, radial, self-aligning, raceway of outer ring spherical. Metric dimensions.	2a, 2b 4, 7	
BWF	**Ball Bearing.** Double row, sealed, inner raceways ground on shaft which extends on both sides, developed for fan and water pump. Metric and inch dimensions.	11	(see table)
	Snap Ring bearings.	8	(see table)

Types of Antifriction Ball and Roller Bearings

Type	Description	Table	Cross Section
TA	**Ball Thrust Bearing.** Single direction, grooved races, flat seats. Metric dimension.	29	
TB	**Ball Thrust Bearing.** Single direction, single or multiple grooved races with flat seats. Inch dimensions.	30a, 30b	
TK	**Ball Bearing.** Single row, angular contact, developed for automobile clutch release. Metric and inch dimensions.	12	(see table)
TN	**Ball Thrust Bearing.** Single direction, grooved races, flat seat, developed for clutch release. Inch dimensions.	13	(see table)
RC	**Cylindrical Roller Bearing.** Single row, double flanged inner and outer rings, non-separable, two direction locating. Metric dimensions.	14	
RF	**Cylindrical Roller Bearing.** Single row, double flanged inner ring, single flanged outer ring, outer ring separable, one direction locating. Metric and inch dimensions.	14	
RG	**Cylindrical Roller Bearing.** Single row, single flanged inner ring, double flanged outer ring, rollers retained by retainment ring recessed in inner ring, non-separable, one direction locating. Metric dimensions.	14	
RJ	**Cylindrical Roller Bearing.** Single row, double flanged outer ring, single flanged inner ring, inner ring separable, one direction locating. Metric dimensions.	14	
RK	**Cylindrical Roller Bearing.** Single row, double flanged inner ring, rollers retained by retainment rings recessed in outer ring, non-separable, non-locating. Metric dimensions.	14	
RM	**Cylindrical Roller Bearing.** Single row, straight inner ring, rollers retained by cage end rings or retainment rings recessed in outer ring, inner ring separable, non-locating. Metric dimensions.	14	
RN	**Cylindrical Roller Bearing.** Single row, double flanged inner ring, straight outer ring, outer ring separable, non-locating. Metric dimensions.	14	
RP	**Cylindrical Roller Bearing.** Single row, double flanged inner ring, double flanged outer ring, with one flange separable, outer ring separable, two direction locating. Metric and inch dimensions.	14	
RS	**Cylindrical Roller Bearing.** Single row, single flanged inner and outer rings, roller retained by flange and single retainment ring recessed in outer ring, inner ring separable, one direction locating. Metric dimensions.	14	
RT	**Cylindrical Roller Bearing.** Single row, double flanged inner ring with one flange separable, double flanged outer ring, inner ring separable, two direction locating. Metric dimensions.	14	
RU	**Cylindrical Roller Bearing.** Single row, straight inner ring, double flanged outer ring, inner ring separable, non-locating. Metric dimensions.	14	

Type	Description	Table	Cross Section
RT	**Cylindrical Roller Bearing.** Single row, double flanged inner ring, single flanged outer ring, rollers retained by flange and single retainment ring recessed in outer ring, non-separable, one direction locating. Metric dimensions.	14	
SD	**Self-aligning Roller Bearing.** Double row, raceway of outer ring spherical. Metric dimensions.	15	
SW	**Self-aligning Roller Bearing.** Double row, raceway of inner ring spherical. Metric dimensions.	15	
	Tolerances, metric annular ball, cylindrical and self-aligning roller bearings (except type BM).	18	(None)
TS	**Tapered Roller Bearing.** Single row; cage or cageless type.	19a to 19e	
TSS	**Tapered Roller Bearing.** Single row, steep angle; cage or cageless (full roller) type. Note—Any single cone listed in the tables of types TS and TSS can be used with flanged outer race (type TSF) or double row (type TDO) in the same series.	20	
TST	**Tapered Roller Bearing.** Single row, tapered bore; cage or cageless type.	21	
TSF	**Tapered Roller Bearing.** Single row, flanged outer race; cage or cageless type.	22	
TDI	**Tapered Roller Bearing.** Double row, single outer races; cage or cageless type.	23	
TDO	**Tapered Roller Bearing.** Double row, single inner races; cage or cageless type. Note—Any single cone listed in the tables of types TS and TSS can be used with flanged outer race (type TSF) or double row (type TDO) in the same series.	24	
TDOS	**Tapered Roller Bearing.** Double row, single inner races, steep angle; cage or cageless type. Note—Any single cone listed in the tables of types TS and TSS can be used with flanged outer race (type TSF) or double row (type TDO) in the same series.	28	
TNA	**Tapered Roller Bearing.** Double row, single inner races, non-adjustable; cage or cageless type.	25	
TNAS	**Tapered Roller Bearing.** Double row, single inner races, non-adjustable, steep angle; cage or cageless type.	27	
NCD	**Needle Bearing.** Shell type, single row, outer race retainment, separable inner race, all dimensions in 1/16 in.	16	
L	**Loose rollers with spherical ends and standard length tolerance of −.020 in.**	17	(none)
	Taper roller bearing tolerances.	26	(none)

TABLE 1—BALL BEARINGS, TYPES BC AND BN

Bearing Numbers and Types		Bore, B			Outside Diameter, D			Indiv. Ring Width, W		Fillet Rad., R[1] In.	Eccentricity Toler., In., Max.	
		Nominal		Toler. +.0000, Minus	Nominal		Toler. +.0000, Minus	Nominal +.000 −.005				
BC	BN	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
8BC10	Automotive sizes 10BN10 through 110BN10	8	0.3150	.0003	22	0.8661	.0004	7	0.2756	.012	.0003	.0006
10BC10		10	0.3937	.0003	26	1.0236	.0004	8	0.3150	.012	.0004	.0006
12BC10		12	0.4724	.0003	28	1.1024	.0004	8	0.3150	.012	.0004	.0006
15BC10		15	0.5906	.0003	32	1.2598	.0005	9	0.3543	.012	.0004	.0008
17BC10		17	0.6693	.0003	35	1.3780	.0005	10	0.3937	.012	.0004	.0008
20BC10		20	0.7874	.0004	42	1.6535	.0005	12	0.4724	.025	.0005	.0008
25BC10		25	0.9843	.0004	47	1.8504	.0005	12	0.4724	.025	.0005	.0008
30BC10		30	1.1811	.0004	55	2.1654	.0005	13	0.5118	.040	.0005	.0010
35BC10		35	1.3780	.0005	62	2.4409	.0005	14	0.5512	.040	.0006	.0010
40BC10		40	1.5748	.0005	68	2.6772	.0005	15	0.5906	.040	.0006	.0010
45BC10		45	1.7717	.0005	75	2.9528	.0005	16	0.6299	.040	.0006	.0010
50BC10		50	1.9685	.0005	80	3.1496	.0005	16	0.6299	.040	.0006	.0010
55BC10		55	2.1654	.0006	90	3.5433	.0006	18	0.7087	.040	.0008	.0014
60BC10		60	2.3622	.0006	95	3.7402	.0006	18	0.7087	.040	.0008	.0014
65BC10		65	2.5591	.0006	100	3.9370	.0006	18	0.7087	.040	.0008	.0014
70BC10		70	2.7559	.0006	110	4.3307	.0006	20	0.7874	.040	.0008	.0014
75BC10		75	2.9528	.0006	115	4.5276	.0006	20	0.7874	.040	.0008	.0014
80BC10		80	3.1496	.0006	125	4.9213	.0008	22	0.8661	.040	.0008	.0016
85BC10		85	3.3465	.0008	130	5.1181	.0008	22	0.8661	.040	.0010	.0016
90BC10		90	3.5433	.0008	140	5.5118	.0008	24	0.9449	.060	.0010	.0016
95BC10		95	3.7402	.0008	145	5.7087	.0008	24	0.9449	.060	.0010	.0016
100BC10		100	3.9370	.0008	150	5.9055	.0008	24	0.9449	.060	.0010	.0016
105BC10		105	4.1339	.0008	160	6.2992	.0010	26	1.0236	.080	.0010	.0018
110BC10		110	4.3307	.0008	170	6.6929	.0010	28	1.1024	.080	.0010	.0018

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.

TABLE 2a—BALL BEARINGS, TYPES BC, BL, BA, BT, BN AND BS

Bearing Numbers and Types						Bore, B			Outside Diameter, D			Indiv. Ring Width, W		Fillet Rad., R[1] In.	Eccent. Toler. In., Max.	
						Nominal		Toler. +.0000, Minus	Nominal		Toler. +.0000, Minus	Nominal +.000 −.005				
BC	BL	BA[2]	BN[2]	BS	BT[2]	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
6BC02	Automotive sizes 20BL02 through 105BL02	Automotive sizes 10BA02 through 100BA02	Automotive sizes 10BN02 through 110BN02	Automotive sizes 12BS02 through 75BS02	Automotive sizes 25BT02 through 90BT02	6	0.2362	.0003	19	0.7480	.0004	6	0.2362	.012	.0003	.0006
7BC02						7	0.2756	.0003	22	0.8661	.0004	7	0.2756	.012	.0003	.0006
9BC02						9	0.3543	.0003	26	1.0236	.0004	8	0.3150	.025	.0003	.0006
10BC02						10	0.3937	.0003	30	1.1811	.0004	9	0.3543	.025	.0004	.0006
12BC02						12	0.4724	.0003	32	1.2598	.0005	10	0.3937	.025	.0004	.0008
15BC02						15	0.5906	.0003	35	1.3780	.0005	11	0.4331	.025	.0004	.0008
17BC02						17	0.6693	.0003	40	1.5748	.0005	12	0.4724	.025	.0004	.0008
20BC02						20	0.7874	.0004	47	1.8504	.0005	14	0.5512	.040	.0005	.0008
25BC02						25	0.9843	.0004	52	2.0472	.0005	15	0.5906	.040	.0005	.0010
30BC02						30	1.1811	.0004	62	2.4409	.0005	16	0.6299	.040	.0005	.0010
35BC02						35	1.3780	.0005	72	2.8346	.0005	17	0.6693	.040	.0006	.0010
40BC02						40	1.5748	.0005	80	3.1496	.0005	18	0.7087	.040	.0006	.0010
45BC02						45	1.7717	.0005	85	3.3465	.0006	19	0.7480	.040	.0006	.0014
50BC02						50	1.9685	.0005	90	3.5433	.0006	20	0.7874	.040	.0006	.0014
55BC02						55	2.1654	.0006	100	3.9370	.0006	21	0.8268	.060	.0008	.0014
60BC02						60	2.3622	.0006	110	4.3307	.0006	22	0.8661	.060	.0008	.0014
65BC02						65	2.5591	.0006	120	4.7244	.0006	23	0.9055	.060	.0008	.0014
70BC02						70	2.7559	.0006	125	4.9213	.0008	24	0.9449	.060	.0008	.0016
75BC02						75	2.9528	.0006	130	5.1181	.0008	25	0.9843	.060	.0008	.0016
80BC02						80	3.1496	.0006	140	5.5118	.0008	26	1.0236	.080	.0008	.0016
85BC02						85	3.3465	.0008	150	5.9055	.0008	28	1.1024	.080	.0010	.0016
90BC02						90	3.5433	.0008	160	6.2992	.0010	30	1.1811	.080	.0010	.0018
95BC02						95	3.7402	.0008	170	6.6929	.0010	32	1.2598	.080	.0010	.0018
100BC02						100	3.9370	.0008	180	7.0866	.0010	34	1.3386	.080	.0010	.0018
105BC02						105	4.1339	.0008	190	7.4803	.0012	36	1.4173	.080	.0010	.0020
110BC02						110	4.3307	.0008	200	7.8740	.0012	38	1.4961	.080	.0010	.0020
120BC02						120	4.7244	.0008	215	8.4646	.0012	40	1.5748	.080	.0010	.0020
130BC02						130	5.1181	.0010	230	9.0551	.0012	40	1.5748	.100	.0012	.0020
140BC02						140	5.5118	.0010	250	9.8425	.0012	42	1.6535	.100	.0012	.0020
150BC02						150	5.9055	.0010	270	10.6299	.0014	45	1.7717	.100	.0012	.0024

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.

[2] Types BN, BA and BT are angular contact bearings which are often used interchangeably.

TABLE 2b—BALL BEARINGS, TYPES BC, BL, BA, BT, BN AND BS

Bearing Numbers and Types						Bore, B			Outside Diameter, D			Indiv. Ring Width, W			Eccent. Toler. In., Max.	
						Nominal		Toler. +.0000, Minus	Nominal		Toler. +.0000, Minus	Nominal +.000 −.005		Fillet Rad., R[1] In.		
BC	BL	BA[2]	BN[2]	BS	BT[2]	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
4BC03	Automotive sizes 20BL03 through 90BL03	Automotive sizes 15BA03 through 60BA03	Automotive sizes 17BN03 through 60BN03	Automotive sizes 20BS03 through 60BS03	Automotive sizes 20BT03 through 60BT03	4	0.1575	.0003	16	0.6299	.0004	5	0.1969	.012	.0003	.0006
5BC03						5	0.1969	.0003	19	0.7480	.0004	6	0.2362	.012	.0003	.0006
10BC03						10	0.3937	.0003	35	1.3780	.0005	11	0.4331	.025	.0004	.0008
12BC03						12	0.4724	.0003	37	1.4567	.0005	12	0.4724	.040	.0004	.0008
15BC03						15	0.5906	.0003	42	1.6535	.0005	13	0.5118	.040	.0004	.0008
17BC03						17	0.6693	.0003	47	1.8504	.0005	14	0.5512	.040	.0004	.0008
20BC03						20	0.7874	.0004	52	2.0472	.0005	15	0.5906	.040	.0005	.0010
25BC03						25	0.9843	.0004	62	2.4409	.0005	17	0.6693	.040	.0005	.0010
30BC03						30	1.1811	.0004	72	2.8346	.0005	19	0.7480	.040	.0005	.0010
35BC03						35	1.3780	.0005	80	3.1496	.0005	21	0.8268	.060	.0006	.0010
40BC03						40	1.5748	.0005	90	3.5433	.0006	23	0.9055	.060	.0006	.0014
45BC03						45	1.7717	.0005	100	3.9370	.0006	25	0.9843	.060	.0006	.0014
50BC03						50	1.9685	.0005	110	4.3307	.0006	27	1.0630	.080	.0006	.0014
55BC03						55	2.1654	.0006	120	4.7244	.0006	29	1.1417	.080	.0008	.0014
60BC03						60	2.3622	.0006	130	5.1181	.0008	31	1.2205	.080	.0008	.0016
65BC03						65	2.5591	.0006	140	5.5118	.0008	33	1.2992	.080	.0008	.0016
70BC03						70	2.7559	.0006	150	5.9055	.0008	35	1.3780	.080	.0008	.0016
75BC03						75	2.9528	.0006	160	6.2992	.0010	37	1.4567	.080	.0008	.0018
80BC03						80	3.1496	.0006	170	6.6929	.0010	39	1.5354	.080	.0008	.0018
85BC03						85	3.3465	.0008	180	7.0866	.0010	41	1.6142	.100	.0010	.0018
90BC03						90	3.5433	.0008	190	7.4803	.0012	43	1.6929	.100	.0010	.0020
95BC03						95	3.7402	.0008	200	7.8740	.0012	45	1.7717	.100	.0010	.0020
100BC03						100	3.9370	.0008	215	8.4646	.0012	47	1.8504	.100	.0010	.0020
105BC03						105	4.1339	.0008	225	8.8583	.0012	49	1.9291	.100	.0010	.0020
110BC03						110	4.3307	.0008	240	9.4488	.0012	50	1.9685	.100	.0010	.0020
120BC03						120	4.7244	.0008	260	10.2362	.0014	55	2.1654	.100	.0010	.0024
130BC03						130	5.1181	.0010	280	11.0236	.0014	58	2.2835	.120	.0012	.0024
140BC03						140	5.5118	.0010	300	11.8110	.0014	62	2.4409	.120	.0012	.0024
150BC03						150	5.9055	.0010	320	12.5984	.0016	65	2.5591	.120	.0012	.0028

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.

[2] Types BN, BA and BT are angular contact bearings which are often used interchangeably.

TABLE 3—BALL BEARINGS, TYPES BC AND BL

Bearing Numbers and Types		Bore, B			Outside Diam., D			Indiv. Ring Width, W		Fillet Rad., R,[1] In.	Eccent. Toler. In., Max.	
		Nominal		Toler. +.0000, Minus	Nominal		Toler. +.0000, Minus	Nominal +.000 −.005				
BC	BL	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
25BC04	.....	25	0.9843	.0004	80	3.1496	.0005	21	0.8268	.060	.0005	.0010
30BC04	30BL04	30	1.1811	.0004	90	3.5433	.0006	23	0.9055	.060	.0005	.0014
35BC04	35BL04	35	1.3780	.0005	100	3.9370	.0006	25	0.9843	.060	.0006	.0014
40BC04	40BL04	40	1.5748	.0005	110	4.3307	.0006	27	1.0630	.080	.0006	.0014
45BC04	45BL04	45	1.7717	.0005	120	4.7244	.0006	29	1.1417	.080	.0006	.0014
50BC04	50BL04	50	1.9685	.0005	130	5.1181	.0008	31	1.2205	.080	.0006	.0016
55BC04	55BL04	55	2.1654	.0006	140	5.5118	.0008	33	1.2992	.080	.0008	.0016
.....	60BL04	60	2.3622	.0006	150	5.9055	.0008	35	1.3780	.080	.0008	.0016
.....	65BL04	65	2.5591	.0006	160	6.2992	.0010	37	1.4567	.080	.0008	.0018

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.

TABLE 4—BALL BEARINGS, TYPE BS

Bearing Number	Bore, B			Outside Diam., D			Indiv. Ring Width, W		Fillet Rad., R,[1] In.	Eccent. Toler. In., Max.	
	Nominal		Toler. +.0000, Minus	Nominal		Toler. +.0000, Minus	Nominal +.000 −.005				
	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
20BS22	20	0.7874	.0004	47	1.8504	.0005	18	0.7087	.040	.0005	.0008
25BS22	25	0.9843	.0004	52	2.0472	.0005	18	0.7087	.040	.0005	.0010
30BS22	30	1.1811	.0004	62	2.4409	.0005	20	0.7874	.040	.0005	.0010
35BS22	35	1.3780	.0005	72	2.8346	.0005	23	0.7874	.040	.0006	.0010
40BS22	40	1.5748	.0005	80	3.1496	.0005	23	0.7874	.040	.0006	.0010
45BS22	45	1.7717	.0005	85	3.3465	.0006	23	0.7874	.040	.0006	.0014
50BS22	50	1.9685	.0005	90	3.5433	.0006	23	0.7874	.040	.0006	.0014
55BS22	55	2.1654	.0006	100	3.9370	.0006	25	0.9843	.060	.0008	.0014
60BS22	60	2.3622	.0006	110	4.3307	.0006	28	1.1024	.060	.0008	.0014
65BS22	65	2.5591	.0006	120	4.7244	.0006	31	1.2205	.060	.0008	.0014
70BS22	70	2.7559	.0006	125	4.9213	.0008	31	1.2205	.060	.0008	.0016
75BS22	75	2.9528	.0006	130	5.5118	.0008	31	1.2205	.060	.0008	.0016
20BS23	20	0.7874	.0004	52	2.0472	.0005	21	0.8268	.040	.0005	.0010
25BS23	25	0.9843	.0004	62	2.4409	.0005	24	0.9449	.040	.0005	.0010
30BS23	30	1.1811	.0004	72	2.8346	.0005	27	1.0630	.040	.0005	.0010
35BS23	35	1.3780	.0005	80	3.1496	.0005	31	1.2205	.060	.0006	.0010
40BS23	40	1.5748	.0005	90	3.5433	.0006	33	1.2992	.060	.0006	.0014
45BS23	45	1.7717	.0005	100	3.9370	.0006	36	1.4173	.060	.0006	.0014
50BS23	50	1.9685	.0005	110	4.3307	.0006	40	1.5748	.080	.0006	.0014
55BS23	55	2.1654	.0006	120	4.7244	.0006	43	1.6929	.080	.0008	.0014
60BS23	60	2.3622	.0006	130	5.5118	.0008	46	1.8110	.080	.0008	.0016
65BS23	65	2.5591	.0006	140	5.5118	.0008	48	1.8898	.080	.0008	.0016
70BS23	70	2.7559	.0006	150	5.9055	.0008	51	2.0079	.080	.0008	.0016
75BS23	75	2.9528	.0006	160	6.2992	.0010	55	2.1654	.080	.0008	.0018

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.

TABLE 5—BALL BEARING, TYPE BIC

Bearing Number	Bore, B		Outside Diam., D		Indiv. Ring Width, W In., Nom. +.000 −.005	Fillet Rad. R[1], In.	Eccent. Toler. In., Max.	
	Nominal	Toler. +.0000, Minus	Nominal	Toler. +.0000, Minus			Inner	Outer
2BIC00	⅛	.0003	⅜	.0004	5/32	.012	.0003	.0006
2BIC02	⅛	.0003	½	.0004	11/64	.012	.0003	.0006
3BIC00	3/16	.0003	½	.0004	5/32	.012	.0003	.0006
4BIC00	¼	.0003	5/8	.0004	.196	.012	.0003	.0006
4BIC02	¼	.0003	¾	.0004	7/32	.016	.0003	.0006
6BIC00	3/8	.0003	7/8	.0004	7/32	.016	.0004	.0006
8BIC00	½	.0003	1⅛	.0004	¼	.016	.0004	.0006
10BIC00	5/8	.0003	1⅜	.0005	9/32	.031	.0004	.0008
12BIC00	¾	.0004	1⅝	.0005	5/16	.031	.0005	.0008
14BIC00	⅞	.0004	1⅞	.0005	3/8	.031	.0005	.0008
16BIC00	1	.0004	2	.0005	3/8	.031	.0005	.0010
18BIC00	1⅛	.0004	2⅛	.0005	3/8	.031	.0005	.0010
20BIC00	1¼	.0005	2¼	.0005	3/8	.031	.0006	.0010
22BIC00	1⅜	.0005	2½	.0005	7/16	.031	.0006	.0010
24BIC00	1½	.0005	2⅝	.0005	7/16	.031	.0006	.0010

TABLE 6—BALL BEARING, TYPE BM

Bearing Number	Bore, B		Toler. +.0000, Minus	Outside Diam., D		Toler. −.0000, Plus	Indiv. Ring Width, W[2] Nominal +.000, −.005		Fillet Rad. R[1], In.	Eccent. Toler. In., Max.	
	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
5BM02	5	.1969	.0003	16	0.6299	.0004	5	.1969	.008	.0003	.0006
6BM002	6	.2362	.0003	24	0.9449	.0004	7	.2756	.012	.0003	.0006
7BM002	7	.2756	.0003	24	0.9449	.0004	7	.2756	.012	.0003	.0006
8BM016	8	.3150	.0003	24	0.9449	.0004	7	.2756	.012	.0003	.0006
9BM001	9	.3543	.0003	28	1.1024	.0004	8	.3150	.012	.0003	.0006
10BM001	10	.3937	.0003	28	1.1024	.0004	8	.3150	.012	.0004	.0006
11BM002	11	.4331	.0003	32	1.2598	.0005	7	.2756	.016	.0004	.0008
12BM002	12	.4724	.0003	32	1.2598	.0005	7	.2756	.016	.0004	.0008
13BM001	13	.5118	.0003	30	1.1811	.0004	7	.2756	.012	.0004	.0008
14BM001	14	.5512	.0003	35	1.3780	.0005	8	.3150	.020	.0004	.0008
15BM001	15	.5906	.0003	35	1.3780	.0005	8	.3150	.020	.0004	.0008
16BM001	16	.6299	.0003	38	1.4961	.0005	10	.3937	.040	.0004	.0008
17BM003	17	.6693	.0003	44	1.7323	.0005	11[3]	.4331	.040	.0004	.0008

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.
[2] Tolerances on assembled bearing width for all sizes, +0.005, −0.005 in.
[3] Outer Ring Width, 10 Mm.

TABLE 7a—BALL BEARINGS, TYPES BE AND BD[2]

Bearing Numbers and Types		Bore, B			Outside Diam., D			Indiv. Ring Width, W Nominal +.000 −.005		Fillet Rad., R[1], In.	Eccent. Toler In., Max.	
		Nominal		Toler. +.0000, Minus	Nominal		Toler. +.0000, Minus					
BE	BD	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
10BE32	...	10	0.3937	.0003	30	1.1811	.0004	14.3	9/16	.025	.0004	.0006
12BE32	.... ..	12	0.4724	.0003	32	1.2598	.0005	15.9	5/8	.025	.0004	.0008
15BE32	15BD32	15	0.5906	.0003	35	1.3780	.0005	15.9	5/8	.025	.0004	.0008
17BE32	17BD32	17	0.6693	.0003	40	1.5748	.0005	17.5	11/16	.025	.0004	.0008
20BE32	20BD32	20	0.7874	.0004	47	1.8504	.0005	20.6	13/16	.040	.0005	.0008
25BE32	25BD32	25	0.9843	.0004	52	2.0472	.0005	20.6	13/16	.040	.0005	.0010
30BE32	30BD32	30	1.1811	.0004	62	2.4409	.0005	23.8	15/16	.040	.0005	.0010
35BE32	35BD32	35	1.3780	.0005	72	2.8346	.0005	27.0	1 1/16	.040	.0006	.0010
40BE32	40BD32	40	1.5748	.0005	80	3.1496	.0005	30.2	1 3/16	.040	.0006	.0010
45BE32	45BD32	45	1.7717	.0005	85	3.3465	.0006	30.2	1 3/16	.040	.0006	.0014
50BE32	50BD32	50	1.9685	.0005	90	3.5433	.0006	30.2	1 3/16	.040	.0006	.0014
55BE32	55BD32	55	2.1654	.0006	100	3.9370	.0006	33.3	1 5/16	.060	.0008	.0014
60BE32	60BD32	60	2.3622	.0006	110	4.3307	.0006	36.5	1 7/16	.060	.0008	.0014
65BE32	65BD32	65	2.5591	.0006	120	4.7244	.0006	38.1	1 1/2	.060	.0008	.0014
70BE32	70BD32	70	2.7559	.0006	125	4.9213	.0008	39.7	1 9/16	.060	.0008	.0016
75BE32	75BD32	75	2.9528	.0006	130	5.1181	.0008	41.3	1 5/8	.060	.0008	.0016
80BE32	80BD32	80	3.1496	.0006	140	5.5118	.0008	44.4	1 3/4	.080	.0008	.0016
85BE32	85BD32	85	3.3465	.0008	150	5.9055	.0008	49.2	1 15/16	.080	.0010	.0016
90BE32	90BD32	90	3.5433	.0008	160	6.2992	.0010	52.4	2 1/16	.080	.0010	.0018
95BE32	95BD32	95	3.7402	.0008	170	6.6929	.0010	55.6	2 3/16	.080	.0010	.0018
100BE32	100BD32	100	3.9370	.0008	180	7.0866	.0010	60.3	2 3/8	.080	.0010	.0018
105BE32	105BD32	105	4.1339	.0008	190	7.4803	.0012	65.1	2 9/16	.080	.0010	.0020
110BE32	110BD32	110	4.3307	.0008	200	7.8740	.0012	69.8	2 3/4	.080	.0010	.0020

TABLE 7b—BALL BEARINGS, TYPES BE AND BD[2]

Bearing Numbers and Types		Bore, B			Outside Diam., D			Indiv. Ring Width, W Nominal +.000 −.005		Fillet Rad., R[1], In.	Eccent. Toler. In., Max.	
		Nominal		Toler. +.0000, Minus	Nominal		Toler. +.0000, Minus					
BE	BD	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
10BE33	10BD33	10	0.3937	.0003	35	1.3780	.0005	19.0	3/4	.025	.0004	.0006
12BE33	12BD33	12	0.4724	.0003	37	1.4567	.0005	19.0	3/4	.040	.0004	.0006
15BE33	15BD33	15	0.5906	.0003	42	1.6535	.0005	19.0	3/4	.040	.0004	.0006
17BE33	17BD33	17	0.6693	.0003	47	1.8504	.0005	22.2	7/8	.040	.0004	.0008
20BE33	20BD33	20	0.7874	.0004	52	2.0472	.0005	22.2	7/8	.040	.0005	.0010
25BE33	25BD33	25	0.9843	.0004	62	2.4409	.0005	25.4	1	.040	.0005	.0010
30BE33	30BD33	30	1.1811	.0004	72	2.8346	.0005	30.2	1 3/16	.040	.0005	.0010
35BE33	35BD33	35	1.3780	.0005	80	3.1496	.0005	34.9	1 3/8	.060	.0006	.0010
40BE33	40BD33	40	1.5748	.0005	90	3.5433	.0006	36.5	1 7/16	.060	.0006	.0014
45BE33	45BD33	45	1.7717	.0005	100	3.9370	.0006	39.7	1 9/16	.060	.0006	.0014
50BE33	50BD33	50	1.9685	.0005	110	4.3307	.0006	44.4	1 3/4	.080	.0006	.0014
55BE33	55BD33	55	2.1654	.0006	120	4.7244	.0006	49.2	1 15/16	.080	.0008	.0014
60BE33	60BD33	60	2.3622	.0006	130	5.1181	.0008	54.0	2 1/8	.080	.0008	.0016
65BE33	65BD33	65	2.5591	.0006	140	5.5118	.0008	58.7	2 5/16	.080	.0008	.0016
70BE33	70BD33	70	2.7559	.0006	150	5.9055	.0008	63.5	2 1/2	.080	.0008	.0016
75BE33	75BD33	75	2.9528	.0006	160	6.2992	.0010	68.3	2 11/16	.080	.0008	.0018
80BE33	80BD33	80	3.1496	.0006	170	6.6929	.0010	68.3	2 11/16	.080	.0008	.0018
85BE33	85BD33	85	3.3465	.0008	180	7.0866	.0010	73.0	2 7/8	.100	.0010	.0018
90BE33	90BD33	90	3.5433	.0008	190	7.4803	.0012	73.0	2 7/8	.100	.0010	.0020
.....	30BD34	30	1.1811	.0004	90	3.5433	.0006	39.7	1 9/16	.060	.0005	.0014
.....	35BD34	35	1.3780	.0005	100	3.9370	.0006	44.4	1 3/4	.060	.0006	.0014
.....	40BD34	40	1.5748	.0005	110	4.3307	.0006	49.2	1 15/16	.080	.0006	.0014
.....	45BD34	45	1.7717	.0005	120	4.7244	.0006	54.0	2 1/8	.080	.0006	.0014
.....	50BD34	50	1.9685	.0005	130	5.1181	.0008	58.7	2 5/16	.080	.0006	.0016

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.

[2] Types BF, BK, BD, BE, BG, BJ and BS are double row bearings of identical dimensions which are often used interchangeably and therefore only the two most popular types, BE and BD, are shown.

Ball-Bearing Snap Rings

SAE Standard

Report of Ball and Roller Bearings Division approved January 1934 and last revised by Ball and Roller Bearings Technical Committee January 1949.

Dimension R—To clear standard fillet radius.
Dimension r—To clear 0.020 in. radius.
Radius Y—Maximum 4 mm (0.016 in.) up to 52 mm OD, and 6 mm (0.024 in.) above 52 mm OD.

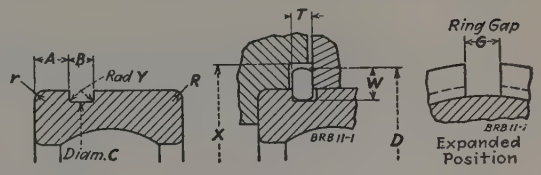


TABLE 8—SNAP RINGS

For Metric Annular Ball Bearings, All Types (Single and Double Row)

Bearing Bores, Mm.			A		Width B	Diam. C	Diam. D	Thick. T	Width W	Gap G	C'tr. Bore Min.
Extra Light	Light	Medium	Extra Light	Light Medium Heavy							
..	10	...	...	.078	.056	1.109	$1\frac{23}{64}$	.042	.125	$\frac{1}{8}$	$1\frac{25}{64}$
15	12	...	.078	.078	.056	1.187	$1\frac{1}{16}$	.042	.125	$\frac{1}{8}$	$1\frac{15}{32}$
17	15	10	.078	.078	.056	1.306	$1\frac{35}{64}$	.042	.125	$\frac{1}{8}$	$1\frac{37}{64}$
...	...	12	...	.078	.056	1.369	$1\frac{39}{64}$	.042	.125	$\frac{1}{8}$	$1\frac{41}{64}$
...	17	...	...	.078	.056	1.500	$1\frac{3}{4}$	.042	.125	$\frac{1}{8}$	$1\frac{25}{32}$
20	...	15	.078	.078	.056	1.565	$1\frac{13}{16}$	.042	.125	$\frac{1}{8}$	$1\frac{27}{32}$
25	20	17	.078	.094	.056	1.756	$2\frac{1}{16}$	.042	.156	$\frac{1}{8}$	$2\frac{3}{32}$
...	25	20	...	.094	.056	1.958	$2\frac{17}{64}$	.042	.156	$\frac{3}{16}$	$2\frac{19}{64}$
30	...	...	.078	...	.056	2.071	$2\frac{3}{8}$	.042	.156	$\frac{3}{16}$	$2\frac{13}{32}$
35	30	25	.078	.125	.078	2.347	$2\frac{21}{32}$	.065	.156	$\frac{3}{16}$	$2\frac{11}{16}$
40	...	...	.094	...	.078	2.552	$2\frac{59}{64}$	.065	.188	$\frac{3}{16}$	$2\frac{63}{64}$
...	35	30	...	.125	.078	2.709	$3\frac{5}{64}$	.065	.188	$\frac{3}{16}$	$3\frac{9}{64}$
45	...	...	.094	...	.078	2.828	$3\frac{13}{64}$	.065	.188	$\frac{3}{16}$	$3\frac{17}{64}$
50	40	35	.094	.125	.078	3.024	$3\frac{13}{32}$	.065	.188	$\frac{3}{16}$	$3\frac{15}{32}$
...	45	...	...	.125	.078	3.221	$3\frac{19}{32}$	.065	.188	$\frac{3}{16}$	$3\frac{21}{32}$
55	50	40	.109	.125	.109	3.417	$3\frac{51}{64}$	.095	.188	$\frac{3}{16}$	$3\frac{55}{64}$
60	...	...	.109	...	.109	3.615	$3\frac{63}{64}$	.095	.188	$\frac{3}{16}$	$4\frac{3}{64}$
65	55	45	.109	.125	.109	3.811	$4\frac{3}{16}$	.095	.188	$\frac{3}{16}$	$4\frac{1}{4}$
70	60	50	.109	.125	.109	4.205	$4\frac{37}{64}$	.095	.188	$\frac{3}{16}$	$4\frac{41}{64}$

A cross index of SAE designations for materials and parts appears after the last standard in this book.

Wheel Ball Bearings

SAE Standard

Report of Ball and Roller Bearings Technical Committee approved January 1949.

TABLE 9—FRONT WHEEL BALL BEARINGS, TYPE BAF

Bearing Numbers				Bore In.	Outside Diam. In.	Widths		
Assembled Bearing	Inner Ring	Outer Ring	Ball Assembly			Over-all	Inner Ring	Outer Ring
Outer Bearings								
12BAF401	12BAF501	12BAF601	12BAF701	0.7503	2.0800	0.708	0.595	0.608
13BAF403	13BAF503	13BAF603	13BAF703	0.8128	2.4370	0.829	0.688	0.729
14BAF405	14BAF505	14BAF605	14BAF705	0.8750	2.6400	1.001	0.637	0.825
15BAF407	15BAF507	15BAF607	15BAF707	0.9370	3.0300	1.031	0.844	0.931
16BAF409	16BAF509	16BAF609	15BAF709	1.0000	3.1425	1.073	0.876	0.973
17BAF411	17BAF511	17BAF611	15BAF711	1.1250	3.5625	1.195	0.970	1.095
11BAF421	11BAF521	11BAF621	11BAF721	0.6875	1.8750	0.687	0.565	0.562
12BAF423	12BAF523	12BAF623	12BAF723	0.7503	2.2500	0.790	0.659	0.690
13BAF425	13BAF525	13BAF625	13BAF725	0.8440	2.2500	0.790	0.659	0.690
15BAF427	15BAF527	15BAF627	15BAF727	0.9379	2.8125	0.910	0.800	0.850
18BAF429	18BAF529	18BAF627	18BAF727	1.1250	3.1875	1.073	0.875	0.973
15BAF435	15BAF535	15BAF627	15BAF727	0.9379	2.3750	0.790	0.659	0.690
Inner Bearings								
19BAF402	19BAF502	19BAF602	19BAF702	1.1904	2.9630	1.145	0.870	0.770
20BAF404	20BAF504	20BAF604	20BAF704	1.2815	3.3750	1.308	0.964	0.933
22BAF406	22BAF506	22BAF606	22BAF706	1.3435	3.5760	1.384	0.980	1.009
23BAF408	23BAF508	23BAF608	23BAF708	1.4384	3.9300	1.470	1.058	1.095
26BAF410	26BAF510	26BAF610	26BAF710	1.6250	4.2375	1.551	1.104	1.176
17BAF422	17BAF522	17BAF622	17BAF722	1.1250	2.5000	0.984	0.845	0.609
21BAF424	21BAF524	21BAF624	21BAF724	1.3128	3.1496	1.226	0.917	0.851
23BAF426	23BAF526	23BAF626	23BAF726	1.4065	3.1496	1.226	0.917	0.851
24BAF428	24BAF528	24BAF628	24BAF728	1.5000	3.7500	1.450	1.070	1.015
26BAF430	26BAF530	26BAF630	26BAF730	1.6250	4.0625	1.562	1.187	1.095
20BAF432	20BAF532	20BAF632	20BAF732	1.2500	2.9630	1.145	0.870	0.770
20BAF442	20BAF542	20BAF642	20BAF742	1.2810	2.9630	1.145	0.870	0.770
20BAF452	20BAF552	20BAF652	20BAF752	1.2815	2.9630	1.145	0.870	0.770
22BAF462	22BAF562	22BAF662	22BAF762	1.3750	2.9630	1.145	0.870	0.770

TABLE 10—REAR WHEEL BALL BEARINGS, TYPE BCB

Bearing Number	Bore		Outside Diameter		Width, In.	
	Mm.	In.	Mm.	In.	Outer	Inner
35BCB082	35	1.3780	72	2.8346	.669	0.984
39BCB084	...	1.5312	80	3.1496	.827	1.083
45BCB088	45	1.7717	100	3.9370	.984	1.378

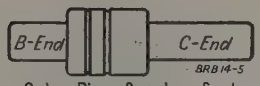
Fan and Water-Pump Ball Bearings

SAE Standard

Report of Ball and Roller Bearings Technical Committee approved January 1949.

Type B, Starred in Table

FIG. 1—TYPE A



Outer Ring Overlaps Seals

FIG. 2—TYPE C

TABLE 11—FAN AND WATER PUMP BALL BEARINGS, TYPE BWF

Bearing Number	Total Shaft L'gth	B End, In.		C End, In.		Shed'g Groove from C End In.	Shaft Diam., In.		NOTES
		Types A & B	Type C	Types A & B	Type C		B End	C End	
BWF229	4 1/32	13/16	7/8	1 9/16	1 5/8	...	.6267	....	Shaft Diam. .499 in. for 1½ in. from C End.
BWF234	4 1/16	55/64	15/16	1 35/64	1 19/32	1 25/64	.6267	.6267	
BWF235	4 1/16	55/64	...	1 35/64	...	...	.6267	.6267	
BWF237	4.160	...	.805	...	1.825	...	.6267	.6267	
BWF238	4.170	...	.160	...	2.480	...	.6267	.6267	
BWF241	4 1/8	33/64	...	1 61/64	...	1 49/64	.6267	.6267	
BWF243	4 1/8	...	15/16	...	1 31/32	1 27/64	.6267	.6267	
BWF245	4.30	...	.140	...	2.565	...	.7460	.7460	See Note 1.
BWF256	4.380	...	.980	...	1.870	...	.6267	.6267	
BWF257	4 25/64	7/8	...	1 55/64	...	1 43/64	.6267	.6267	.159 hole 3/8 in. from B End.
BWF258	4 25/64	...	15/16	...	1 59/64	1 43/64	.6267	.6267	
BWF260	4.406	1	1.060	1¾	1.809	...	.6267	.6267	Snap Ring groove in B End. Extra groove in cup O. D., 5/16 in. off center.
BWF261	4.760	...	1.160	...	2.070	1.819	.6267	.6267	
BWF262	4 29/64	1 3/16	...	1 39/64	...	1 27/64	.6267	.6267	
BWF263	4 29/64	...	1¼	...	1 43/64	1 31/64	.6267	.6267	
BWF266	4 15/32	1 1/64	...	1 51/64	...	...	.6267	.6267	
BWF268	4 15/32	...	1 5/64	...	1 55/64	...	.6267	.6267	
BWF269	4 15/32	...	1 5/64	...	1 55/64	1 35/64	....	.6267	.552 in. diam. for 1 in. on B End.
BWF274	4 33/64	2 49/64	...	3/32	...	...	.6267	.6267	
*BWF278	4 9/16	43/64	...	2 15/64	..	...	.6267	.6267	
BWF279	4 9/16	..	15/16	...	2 3/32	...	.6267	.6267	
BWF283	4 13/16	1 1/16	...	2 3/32	...	...	.6280	.6280	See Note 2.
BWF284	4 13/16	..	1 1/8	...	2 5/32	1 15/16	.6280	.6280	Drill .157 in. hole 3/8 in. from B End.
BWF288	4 27/32	..	1 29/64	...	1 55/64	...	.6267	.6267	
BWF290	4.869	1 5/16	...	2.026	...	...	.6267	.6267	
BWF299	5 1/32	61/64	1 1/64	2 27/64	2 31/64	2 15/64	.6267	.6267	
BWF302	5 1/32	61/64	1 1/64	2 27/64	2 31/64	...	.6267	.6267	
BWF307	5 1/32	61/64	...	2 27/64	...	...	.6267	.6267	
BWF315	5 1/32	..	1 7/32	...	2 9/32	2 1/32	.6280	.6280	See Note 3.
BWF316	5 1/32	...	1 7/32	...	2 9/32	2 1/32	.6267	.6267	⅛ in. hole in center of outer ring.
BWF318	5 1/32	1 11/16	...	1 11/16	...	...	.6267	.6267	
BWF322	5 5/64	1 3/16	...	2 15/64	...	...	.6267	.6267	
BWF324	5 1/8	3/32	5/32	3 3/8	3 7/16	...	.6267	.6267	
BWF330	5 7/16	2 15/64	...	1 35/64	...	...	.6267	.6267	
BWF340	5 5/8	1 33/64	1 19/32	2 29/64	2½	...	.6267	.6267	

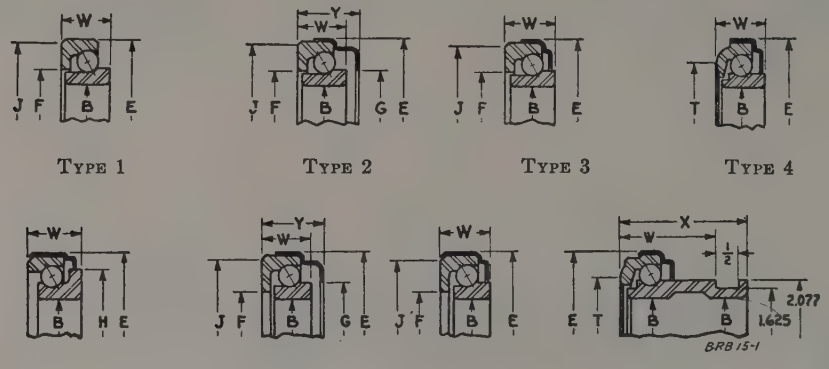
Note 1—O. D. outer 1.500; 2.125 long. Two keyways, shedding groove and slot in C End.
Note 2—Drill .159 in. hole 3/8 in. from B End.
Note 3—.157 in. hole 3/8 in. from B End.

Clutch-Release Ball Bearings

SAE Standard

Report of Ball and Roller Bearing Technical Committee approved January 1949.

Angular Contact Type TK



TYPE 1 TYPE 2 TYPE 3 TYPE 4

TYPE 7 TYPE 5 TYPE 6 TYPE 8

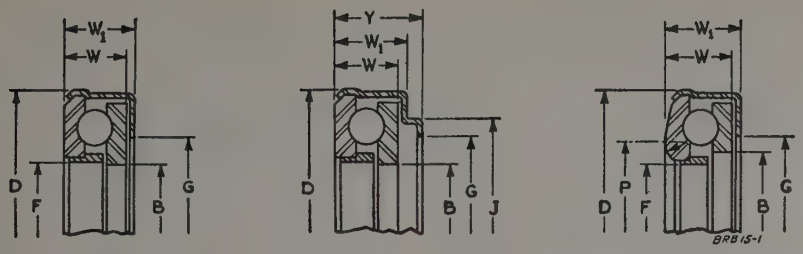
TABLE 12—ANGULAR CONTACT, TYPE TK BEARINGS

Bearing Number	Type	Bore B	Outside Diam.		Widths			Outer Bore F, Max.	H's'g Bore G, Min.	Inner O. D. H, Min.	Cont. Diam. T	Clutch Finger Face O. D. J, Min.
			D	E, Max.	W	X	Y, Max.					
22TK306	8	1 3/8	...	2 13/16	1 1/4	1 7/8	...	....	....	....	1 15/16	....
22TK307	8	1 3/8	...	2 13/16	63/64	1 39/64	...	....	....	....	1 15/16	....
23TK302	1[1]	1 7/16	2 9/16	...	11/16	...	...	1 27/32	....	....	....	2 3/8
23TK315	2	1 7/16	...	2 5/8	11/16	...	7/8	1 27/32	1 27/32	....	....	2 3/8
23TK330	5	1 7/16	...	2 5/8	11/16	...	7/8	1.458	1 27/32	....	....	2 1/2
24TK308	3	1 1/2	...	2 13/16	5/8	...	...	1 3/4	....	....	....	2 1/2
24TK307	4	1 1/2	...	2 13/16	11/16	...	...	....	....	....	2 1/4	....
26TK324	6	1 5/8	...	2 19/32	5/8	...	...	1.010	....	....	....	2 1/4
26TK302	1[1]	1 5/8	2 3/4	...	11/16	...	...	2 1/32	....	....	....	2 9/16
26TK314	2	1 5/8	...	2 13/16	11/16	...	53/64	2 1/32	2 1/32	....	....	2 9/16
29TK302	1[1]	1 13/16	3	...	3/4	...	...	2 1/4	....	....	....	2 13/16
29TK316	2	1 13/16	...	3 1/16	3/4	...	29/32	2 1/4	2 9/32	....	....	2 13/16
32TK328	5	2	...	3.237	11/16	...	51/64	2.035	2 7/16	....	....	3 5/64
32TK313	2	2	...	3 1/4	3/4	...	29/32	2 7/16	2 7/16	....	....	3
32TK303	1[1]	2	3 3/16	...	3/4	...	...	2 7/16	....	....	....	3
326TK329	5	2.1355	...	3 1/2	3/4	...	29/32	2.270	2 11/16	....	....	3 1/4
36TK314	2	2 1/4	...	3 1/2	3/4	...	29/32	2 9/16	2 11/16	....	....	3 1/4
36TK301	1[1]	2 1/4	3 7/16	...	3/4	...	...	2 9/16	....	....	....	3 1/4
36TK327	5	2 1/4	...	3 1/2	3/4	...	29/32	2.270	2 11/16	....	....	3 1/4
38TK306	7[1]	2 3/8	...	3 7/8	7/8	...	...	3.288	....	3 3/8	....	....
40TK306	7[1]	2 1/2	...	4.075	1 1/16	...	...	3.494	....	3 7/16	....	....
44TK314	2	2 3/4	...	4.075	13/16	...	1	3 13/64	3 13/64	....	....	3 13/16
44TK330	5	2 3/4	...	4.075	13/16	...	1	2.770	3 13/64	....	....	3 13/16
44TK302	1[1]	2 3/4	4	...	13/16	...	...	3 13/64	....	....	....	3 13/16

[1] Outside diameter mounted.

(*Continued on next page.*)

Thrust Type TN



Type 1 Type 2 Type 3

TABLE 13—THRUST, TYPE TN BEARINGS

Bearing Number	Type	Bore B	Outside Diam. D, Max.	H's'g Bore G, Min.	J, Max.	F,[1] Min.	P Diam. to Center of Rad.	Widths		
								W	W_1, Max.	Y, Max.
306TN342	1	1½	2 13/16	2⅛	....	....	....	⅝	.682	...
306TN343	3	1½	2 13/16	2⅛	....	1.516	2¼	11/16	.724	....
307TN334	1	1 9/16	3⅛	2 13/32	....	....	....	11/16	.744	...
308TN334	1	1⅝	3⅛	2 13/32	....	....	....	11/16	.744	....
310TN331	2	1 11/16	3 1/16	2⅛	2½	....	....	⅝	.673	.750
311TN332	3	1.6910	2 13/16	2⅛	....	1.506	1 15/16	11/16	.744	....
312TN334	1	1¾	3⅛	2 13/32	....	....	....	11/16	.744	....
316TN335	1	1⅞	3 21/64	2 7/16	....	....	....	¾	.807	....
320TN340	1	2	3 3/16	2½	....	....	....	¾	.807	....
321TN342	1	2 1/16	3 3/16	2½	....	....	....	¾	.807	....
329TN340	1	2¼	3 11/16	2 11/16	....	....	....	¾	.807	....
331TN334	1	2⅜	3 11/16	2 11/16	....	2.255	....	¾	.807	....
333TN332	1	2½	4⅛	3 1/16	....	....	....	13/16	.870	....
335TN334	1	2¾	4½	3 5/16	....	....	....	13/16	.870	....
335TN332	2	2¾	4 1/16	3 15/64	3 15/32	....	....	13/16	.860	1.000
337TN332	1	3¼	5 7/32	4	....	....	....	13/16	.890	....

[1] F given only where smaller than B.

Cylindrical Roller Bearings

SAE Standard

Report of Ball and Roller Bearings Division approved January 1944 and last revised by Ball and Roller Bearings Technical Committee January 1949.

TABLE 14a—CYLINDRICAL ROLLER BEARINGS, TYPES RN, RU, RF, RY, RJ, RM, RK, RS, RC, RG, RP, RT

Bearing Number, Type RN[2]	Bore			Outside Diameter			Indiv. Ring Width, Nominal +.000 −.005		Fillet Rad. R[1], In.	Eccent. Toler., In., Max.	
	Nominal		Toler. +.0000 Minus	Nominal		Toler. +.0000 Minus					
	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
17RN02	17	0.6693	.0003	40	1.5748	.0005	12	0.4724	.025	.0004	.0008
20RN02	20	0.7874	.0004	47	1.8504	.0005	14	0.5512	.040	.0005	.0008
25RN02	25	0.9843	0004	52	2.0472	.0005	15	0.5906	.040	.0005	.0010
30RN02	30	1.1811	.0004	62	2.4409	.0005	16	0.6299	.040	.0005	.0010
35RN02	35	1.3780	.0005	72	2.8346	.0005	17	0.6693	.040	.0006	.0010
40RN02	40	1.5748	.0005	80	3.1496	.0005	18	0.7087	.040	.0006	.0010
45RN02	45	1.7717	.0005	85	3.3465	.0006	19	0.7480	.040	.0006	.0014
50RN02	50	1.9685	.0005	90	3.5433	.0006	20	0.7874	.040	.0006	.0014
55RN02	55	2.1654	.0006	100	3.9370	.0006	21	0.8268	.060	.0008	.0014
60RN02	60	2.3622	.0006	110	4.3307	.0006	22	0.8661	.060	.0008	.0014
65RN02	65	2.5591	.0006	120	4.7244	.0006	23	0.9055	.060	.0008	.0014
70RN02	70	2.7559	.0006	125	4.9213	.0008	24	0.9449	.060	.0008	.0016
75RN02	75	2.9528	.0006	130	5.1181	.0008	25	0.9843	.060	.0008	.0016
80RN02	80	3.1496	.0006	140	5.5118	.0008	26	1.0236	.080	.0008	.0016
85RN02	85	3.3465	.0008	150	5.9055	.0008	28	1.1024	.080	.0010	.0016
90RN02	90	3.5433	.0008	160	6.2992	.0010	30	1.1811	.080	.0010	.0018
95RN02	95	3.7402	.0008	170	6.6929	.0010	32	1.2598	.080	.0010	.0018
100RN02	100	3.9370	.0008	180	7.0866	.0010	34	1.3386	.080	.0010	.0018
105RN02	105	4.1339	.0008	190	7.4803	.0012	36	1.4173	.080	.0010	.0020
110RN02	110	4.3307	.0008	200	7.8740	.0012	38	1.4961	.080	.0010	.0020
120RN02	120	4.7244	.0008	215	8.4646	.0012	40	1.5748	.080	.0010	.0020
130RN02	130	5.1181	.0010	230	9.0551	.0012	40	1.5748	.100	.0012	.0020
140RN02	140	5.5118	.0010	250	9.8425	.0012	42	1.6535	.100	.0012	.0020
150RN02	150	5.9055	.0010	270	10.6299	.0014	45	1.7717	.100	.0012	.0024

[1]The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.
[2]Same data applicable to Types RU, RF, RY, RJ, RM, RK, RS, RC, RG, RP and RT.

TABLE 14b—CYLINDRICAL ROLLER BEARINGS, TYPES RN, RU, RF, RY, RJ, RM, RK, RS, RC, RG, RP, RT

Bearing Number, Type RN[2]	Bore			Outside Diameter			Indiv. Ring Width, Nominal +.000 −.005		Fillet Rad. R[1], In.	Eccent. Toler., In., Max.	
	Nominal		Toler. +.0000 Minus	Nominal		Toler. +.0000 Minus					
	Mm.	In.		Mm.	In.		Mm.	In.		Inner	Outer
17RN03	17	0.6693	.0003	47	1.8504	.0005	14	0.5512	.040	.0004	.0008
20RN03	20	0.7874	.0004	52	2.0472	.0005	15	0.5906	.040	.0005	.0010
25RN03	25	0.9843	.0004	62	2.4409	.0005	17	0.6693	.040	.0005	.0010
30RN03	30	1.1811	.0004	72	2.8346	.0005	19	0.7480	.040	.0005	.0010
35RN03	35	1.3780	.0005	80	3.1496	.0005	21	0.8268	.060	.0006	.0010
40RN03	40	1.5748	.0005	90	3.5433	.0006	23	0.9055	.060	.0006	.0014
45RN03	45	1.7717	.0005	100	3.9370	.0006	25	0.9843	.060	.0006	.0014
50RN03	50	1.9685	.0005	110	4.3307	.0006	27	1.0630	.080	.0006	.0014
55RN03	55	2.1654	.0006	120	4.7244	.0006	29	1.1417	.080	.0008	.0014
60RN03	60	2.3622	.0006	130	5.1181	.0008	31	1.2205	.080	.0008	.0016
65RN03	65	2.5591	.0006	140	5.5118	.0008	33	1.2992	.080	.0008	.0016
70RN03	70	2.7559	.0006	150	5.9055	.0008	35	1.3780	.080	.0008	.0016
75RN03	75	2.9528	.0006	160	6.2992	.0010	37	1.4567	.080	.0008	.0018
80RN03	80	3.1496	.0006	170	6.6929	.0010	39	1.5354	.080	.0008	.0018
85RN03	85	3.3465	.0008	180	7.0866	.0010	41	1.6142	.100	.0010	.0018
90RN03	90	3.5433	.0008	190	7.4803	.0012	43	1.6929	.100	.0010	.0020
95RN03	95	3.7402	.0008	200	7.8740	.0012	45	1.7717	.100	.0010	.0020
100RN03	100	3.9370	.0008	215	8.4646	.0012	47	1.8504	.100	.0010	.0020
105RN03	105	4.1339	.0008	225	8.8583	.0012	49	1.9291	.100	.0010	.0020
110RN03	110	4.3307	.0008	240	9.4488	.0012	50	1.9685	.100	.0010	.0020
120RN03	120	4.7244	.0008	260	10.2362	.0014	55	2.1654	.100	.0010	.0024
130RN03	130	5.1181	.0010	280	11.0236	.0014	58	2.2835	.120	.0012	.0024
140RN03	140	5.5118	.0010	300	11.8110	.0014	62	2.4409	.120	.0012	.0024
150RN03	150	5.9055	.0010	320	12.5984	.0016	65	2.5591	.120	.0012	.0028

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.
[2] Same data applicable to Types RU, RF, RY, RJ, RM, RK, RS, RC, RG, RP and RT.

TABLE 15—SELF-ALIGNING ROLLER BEARINGS, TYPES SD AND SW

Bearing Numbers and Types		Bore			Outside Diameter			Width, +.000, −.005		Fillet Rad. R[1]
SD	SW	Mm.	In.	Toler. +.0000 Minus	Mm.	In.	Toler. +.0000 Minus	Mm.	In.	In.
35SD02		35	1.3780	.0005	72	2.8346	.0005	17	0.6693	.04
40SD02		40	1.5748	.0005	80	3.1496	.0005	18	0.7087	.04
45SD02		45	1.7717	.0005	85	3.3465	.0006	19	0.7480	.04
50SD02		50	1.9685	.0005	90	3.5433	.0006	20	0.7874	.04
55SD02		55	2.1654	.0006	100	3.9370	.0006	21	0.8268	.06
60SD02		60	2.3622	.0006	110	4.3307	.0006	22	0.8661	.06
65SD02		65	2.5591	.0006	120	4.7244	.0006	23	0.9055	.06
70SD02		70	2.7559	.0006	125	4.9213	.0008	24	0.9449	.06
75SD02		75	2.9528	.0006	130	5.1181	.0008	25	0.9843	.06
35SD03		35	1.3780	.0005	80	3.1496	.0005	21	0.8268	.06
40SD03		40	1.5748	.0005	90	3.5433	.0006	23	0.9055	.06
45SD03		45	1.7717	.0005	100	3.9370	.0006	25	0.9843	.06
50SD03		50	1.9685	.0005	110	4.3307	.0006	27	1.0630	.08
55SD03		55	2.1654	.0006	120	4.7244	.0006	29	1.1417	.08
60SD03		60	2.3622	.0006	130	5.1181	.0008	31	1.2205	.08
65SD03		65	2.5591	.0006	140	5.5118	.0008	33	1.2992	.08
70SD03		70	2.7559	.0006	150	5.9055	.0008	35	1.3780	.08
75SD03		75	2.9528	.0006	160	6.2992	.0010	37	1.4567	.08
80SD22		80	3.1496	.0006	140	5.5118	.0008	33	1.2992	.08
85SD22		85	3.3465	.0008	150	5.9055	.0008	36	1.4173	.08
90SD22		90	3.5433	.0008	160	6.2992	.0010	40	1.5748	.08
95SD22		95	3.7402	.0008	170	6.6929	.0010	43	1.6929	.08
100SD22	80SW23 through 150SW22	100	3.9370	.0008	180	7.0866	.0010	46	1.8110	.08
110SD22		110	4.3307	.0008	200	7.8740	.0012	53	2.0866	.08
120SD22		120	4.7244	.0008	215	8.4646	.0012	58	2.2835	.08
130SD22		130	5.1181	.0010	230	9.0551	.0012	64	2.5197	.10
140SD22		140	5.5118	.0010	250	9.8425	.0012	68	2.6772	.10
150SD22		150	5.9055	.0010	270	10.6299	.0014	73	2.8740	.10

Bearing Numbers and Types		Bore			Outside Diameter			Width, +.000, −.005		Fillet Rad. R[1]
SD	SW	Mm.	In.	Toler. +.0000 Minus	Mm.	In.	Toler. +.0000 Minus	Mm.	In.	In.
40SD23		40	1.5748	.0005	90	3.5433	.0006	33	1.2992	.06
45SD23		45	1.7717	.0005	100	3.9370	.0006	36	1.4173	.06
50SD23		50	1.9685	.0005	110	4.3307	.0006	40	1.5748	.08
55SD23		55	2.1654	.0006	120	4.7244	.0006	43	1.6929	.08
60SD23		60	2.3622	.0006	130	5.1181	.0008	46	1.8110	.08
65SD23		65	2.5591	.0006	140	5.5118	.0008	48	1.8898	.08
70SD23		70	2.7559	.0006	150	5.9055	.0008	51	2.0079	.08
75SD23		75	2.9528	.0006	160	6.2992	.0010	55	2.1654	.08
80SD23		80	3.1496	.0006	170	6.6929	.0010	58	2.2835	.08
85SD23		85	3.3465	.0008	180	7.0866	.0010	60	2.3622	.10
90SD23		90	3.5433	.0008	190	7.4803	.0012	64	2.5197	.10
95SD23		95	3.7402	.0008	200	7.8740	.0012	67	2.6378	.10
100SD23	40SW23 through 150SW23	100	3.9370	.0008	215	8.4646	.0012	73	2.8740	.10
110SD23		110	4.3307	.0008	240	9.4488	.0012	80	3.1496	.10
120SD23		120	4.7244	.0008	260	10.2362	.0014	86	3.3858	.10
130SD23		130	5.1181	.0010	280	11.0236	.0014	93	3.6614	.12
140SD23		140	5.5118	.0010	300	11.8110	.0014	102	4.0157	.12
150SD23		150	5.9055	.0010	320	12.5984	.0016	108	4.2520	.12

[1]The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.

Needle Roller Bearings

SAE Standard

Report of Ball and Roller Bearings Technical Committee approved January 1949.

TABLE 16—NEEDLE ROLLER BEARINGS—TYPE NCD

Bearing Number	Bore	Width	Outside Diam.
6NCD1212	0.3750	3/4	3/4
6NCD1213	0.3750	3/4	13/16
8NCD1216	0.5000	3/4	1
10NCD1218	0.6250	3/4	1 1/8
10NCD1219	0.6250	3/4	1 3/16
10NCD1618	0.6250	1	1 1/8
12NCD1220	0.7500	3/4	1 1/4
12NCD1620	0.7500	1	1 1/4
12NCD1621	0.7500	1	1 5/16
12NCD2421	0.7500	1 1/2	1 5/16
13NCD1220	0.8125	3/4	1 1/4
13NCD1620	0.8125	1	1 1/4
13NCD1621	0.8125	1	1 5/16
14NCD1622	0.8750	1	1 3/8
15NCD1622	0.9375	1	1 3/8
16NCD1624	1.0000	1	1 1/2
18NCD1628	1.1250	1	1 3/4
18NCD2026	1.1250	1 1/4	1 5/8
19NCD2030	1.1875	1 1/4	1 7/8
20NCD2030	1.2500	1 1/4	1 7/8
23NCD2434	1.4375	1 1/2	2 1/8
24NCD1634	1.5000	1	2 1/8
24NCD2434	1.5000	1 1/2	2 1/8
30NCD2440	1.8750	1 1/2	2 1/2

TABLE 17—LOOSE ROLLERS, TYPE L

Bearing Number	Size (Diam. x Length)	Bearing Number	Size (Diam. x Length)
0312L19	.0312 x .19	1094L62	.1094 x 0.62
0312L25	.0312 x .25	1094L75	.1094 x 0.75
0312L31	.0312 x .31	1094L88	.1094 x 0.88
		1094L1000	.1094 x 1.00
0469L25	.0469 x .25		
0469L31	.0469 x .31	125L75	.1250 x 0.75
0469L38	.0469 x .38	125L88	.1250 x 0.88
0469L44	.0469 x .44	125L1000	.1250 x 1.00
		125L1120	.1250 x 1.12
0625L38	.0625 x .38	125L1250	.1250 x 1.25
0625L44	.0625 x .44		
0625L5	.0625 x .50	1562L1000	.1562 x 1.00
0625L56	.0625 x .56	1562L1250	.1562 x 1.25
0625L62	.0625 x .62	1562L1500	.1562 x 1.50
0781L44	.0781 x .44	1875L1000	.1875 x 1.00
0781L5	.0781 x .50	1875L1250	.1875 x 1.25
0781L56	.0781 x .56	1875L1500	.1875 x 1.50
0781L62	.0781 x .62		
0781L69	.0781 x .69	2188L1000	.2188 x 1.00
0781L75	.0781 x .75	2188L1250	.2188 x 1.25
		2188L1500	.2188 x 1.50
0938L56	.0938 x .56		
0938L62	.0938 x .62	25L5	.2500 x 0.50
0938L69	.0938 x .69	25L75	.2500 x 0.75
0938L75	.0938 x .75	25L1000	.2500 x 1.00
0938L81	.0938 x .81	25L1250	.2500 x 1.25
0938L88	.0938 x .88	25L1500	.2500 x 1.50
		25L1750	.2500 x 1.75

Ball- and Roller-Bearing Tolerances

SAE Standard

Report of Ball and Roller Bearings Division approved January 1944 and last revised by Ball and Roller Bearings Technical Committee January 1949.

TABLE 18—TOLERANCES OF METRIC ANNULAR BALL, CYLINDRICAL AND SELF-ALIGNING ROLLER BEARINGS EXCEPT TYPE BM (Magneto)
TOLERANCES IN .0001 IN.

INNER RINGS

Bore, Mm.		Bore Toler.				
		dm		d Min.	d Max.	Eccent.
Over	Incl.	Low (−)	High (+)	Minus	Plus	
0	9	3	0	4	1	3
9	18	3	0	4	1	4
18	30	4	0	5	1	5
30	50	5	0	7	2	6
50	80	6	0	8	2	8
80	120	8	0	11	3	10
120	180	10	0	13	3	12
180	250	12	0	16	4	16
250	315	14	0	18	4	20
315	400	16	0	20	4	24
400	500	18	0	23	5	26

OUTER RINGS

Outside Diam., Mm.		Outside Diameter Toler.				
		Dm		D max.	D min.	Eccent.
Over	Incl.	High (+)	Low (−)	Plus	Minus	
0	18	0	4	1	5	6
18	30	0	4	1	5	6
30	50	0	5	2	7	8
50	80	0	5	2	7	10
80	120	0	6	3	9	14
120	150	0	8	3	11	16
150	180	0	10	3	13	18
180	250	0	12	4	16	20
250	315	0	14	4	18	24
315	400	0	16	4	20	28
400	500	0	18	5	23	32
500	630	0	20	6	26	40

WIDTH OF INDIVIDUAL INNER OR OUTER RING
(Bearings Other Than Duplex)

Nom. Bore, Mm.		Width Toler.	
Over	Incl.	Plus	Minus
0	180	0	50
180	315	0	100
315	400	0	160
400	500	0	180
500	630	0	220

TOTAL WIDTH OF INNER OR OUTER RINGS
(Duplex Bearings[1])

Nom. Bore, Mm.		Width Toler.	
Over	Incl.	Plus	Minus
0	80	0	200
80	180	0	300
180	315	0	400
315	400	0	500

[1] If other than a pair of bearings is involved, the tolerance is in proportion to the number of bearings.

A cross index of SAE designations for materials and parts appears after the last standard in this book.

Taper Roller Bearings

SAE Standard

Report of Ball and Roller Bearings Division approved January 1912 and last revised by Ball and Roller Bearings Technical Committee January 1949.

[This SAE Standard applies to cage or cageless types of taper roller bearings.]

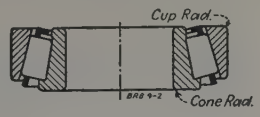


TABLE 19a—TAPER ROLLER BEARINGS—TYPE TS

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.	Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
A2037–A2126	0.3750	1.2595	0.3940	3/64	3/64	1985–1932	1.1250	2.3125	0.7500	1/32	3/64
A2047–A2126	0.4720	1.2595	0.3940	1/32	3/64	15112–15250	1.1250	2.5000	0.8125	3/64	3/64
A4050–A4138	0.5000	1.3775	0.4330	3/64	3/64	2689–2631	1.1250	2.6150	0.9375	3/64	3/64
A4059–A4138	0.5900	1.3775	0.4330	1/32	3/64	02474–02420	1.1250	2.6875	0.8750	1/32	1/16
A6062–A6157	0.6250	1.5745	0.4730	3/64	3/64	2578–2523	1.1250	2.7500	0.9375	3/32	3/64
17580–17520	0.6250	1.6875	0.6563	1/16	1/16	26112–26283	1.1250	2.8345	0.7480	1/16	1/16
05062–05185	0.6250	1.8504	0.5662	1/16	3/64	3198–3120	1.1250	2.8593	1.1875	3/64	1/8
09062–09196	0.6250	1.9380	0.9063	1/32	1/16	02872–02820	1.1250	2.8750	0.8750	1/32	1/8
A6067–A6157	0.6690	1.5745	0.4730	1/32	3/64	2690–2631	1.1562	2.6150	0.9375	3/64	3/64
A6075–A6157	0.7500	1.5745	0.4730	.040	3/64	17118–17244	1.1805	2.4410	0.6300	1/16	1/16
05075–05185	0.7500	1.8504	0.5662	3/64	3/64	15117–15250	1.1805	2.5000	0.8125	3/64	3/64
09078–09196	0.7500	1.9380	0.9063	3/64	1/16	14117A–14276	1.1810	2.7170	0.7813	3/64	3/64
1775–1729	0.7500	2.2400	0.7625	1/16	3/64	17119–17244	1.1875	2.4410	0.6300	1/16	1/16
05079–05185	0.7870	1.8504	0.5662	1/16	3/64	2558–2523	1.1875	2.7500	0.9375	3/32	3/64
07079–07204	0.7874	2.0470	0.5910	1/16	3/64	3191–3120	1.1875	2.8593	1.1875	3/64	1/8
12580–12520	0.8125	1.9380	0.7813	1/16	1/16	15118–15250	1.1895	2.5000	0.8125	3/64	3/64
07087–07204	0.8750	2.0470	0.5910	3/64	3/64	14119A–14276	1.1900	2.7170	0.7813	1/32	3/64
1380–1329	0.8750	2.1250	0.7625	1/16	1/16	1674–1620	1.2450	2.6250	0.8125	1/16	1/16
1755–1729	0.8750	2.2400	0.7625	3/64	3/64	08125–08231	1.2500	2.3125	0.5781	.040	.040
1280–1220	0.8750	2.2500	0.8750	1/32	1/16	02475–02420	1.2500	2.6875	0.8750	3/64	1/16
1779–1729	0.9375	2.2400	0.7625	1/32	3/64	14125A–14276	1.2500	2.7170	0.7813	3/64	3/64
3659–3620	0.9375	2.4375	1.1250	3/32	1/8	2582–2523	1.2500	2.7500	0.9375	3/64	3/64
2685–2631	0.9375	2.6150	0.9375	1/32	3/64	3193–3120	1.2500	2.8593	1.1875	3/64	1/8
26093–26283	0.9375	2.8345	0.7480	3/32	1/16	02875–02820	1.2500	2.8750	0.8750	3/64	1/8
07098–07204	0.9835	2.0470	0.5910	1/16	3/64	2875–2820	1.2500	2.8750	0.8750	3/64	1/8
07100–07204	1.0000	2.0470	0.5910	.040	3/64	3476–3420	1.2500	3.1250	1.1563	3/64	1/8
15578–15520	1.0000	2.2500	0.6875	3/64	1/16	346–332	1.2500	3.1496	0.8268	1/32	3/64
1986–1932	1.0000	2.3125	0.7500	3/64	3/64	26126–26283	1.2600	2.8345	0.7480	1/16	1/16
15100–15250	1.0000	2.5000	0.8125	3/64	3/64	14130–14276	1.3125	2.7170	0.7813	3/64	3/64
2687–2631	1.0000	2.6150	0.9375	3/64	3/64	2585–2523	1.3125	2.7500	0.9375	3/64	3/64
26100–26283	1.0000	2.8345	0.7480	1/16	1/16	2876–2820	1.3125	2.8750	0.8750	3/64	1/8
15580–15520	1.0625	2.2500	0.6875	3/64	1/16	2785–2720	1.3125	3.0000	0.9375	3/64	1/8

TABLE 19b—TAPER ROLLER BEARINGS—TYPE TS (*Continued*)

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.	Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
31590–31520	1.3125	3.0000	1.1563	1/32	1/8	444–432	1.5000	3.7500	1.0938	3/64	3/32
14137A–14276	1.3750	2.7170	.7813	1/16	3/64	542–532X	1.5000	4.2500	1.4375	3/64	1/8
02877–02820	1.3750	2.8750	.8750	3/64	1/8	26881–26820	1.5625	3.1562	1.0000	3/64	1/8
2878–2820	1.3750	2.8750	.8750	1/32	1/8	3382–3320	1.5625	3.1562	1.1563	3/64	1/8
25878–25820	1.3750	2.8750	.9375	3/64	3/32	422–414	1.5625	3.4843	1.0625	3/64	1/32
2786–2720	1.3750	3.0000	.9375	13/64	1/8	28158–28315	1.5748	3.1495	.8270	1/16	1/16
36137–36300	1.3750	3.0000	1.1563	1/16	1/8	344–332	1.5748	3.1496	.8268	3/64	3/64
31593–31520	1.3750	3.0000	1.1563	3/64	1/8	420–414	1.5748	3.4843	1.0625	3/64	1/32
3478–3420	1.3750	3.1250	1.1563	3/64	1/8	24780–24720	1.6250	3.0000	.8750	3/64	1/32
335–332	1.3750	3.1496	.8268	1/32	3/64	11162–11315	1.6250	3.1495	.7090	1/16	1/16
3379–3320	1.3750	3.1562	1.1563	3/64	1/8	342–332	1.6250	3.1496	.8268	3/64	3/64
417–414	1.3750	3.4843	1.0625	1/32	1/32	26882–26820	1.6250	3.1562	1.0000	3/64	1/8
449–432	1.3750	3.7500	1.0938	1/32	3/32	3877–3820	1.6250	3.3750	1.1875	3/64	1/8
19138–19283	1.3770	2.8345	.6700	1/16	1/16	3577–3525	1.6250	3.4375	1.1875	3/64	1/8
339–332	1.3779	3.1496	.8268	1/32	3/64	419–414	1.6250	3.4843	1.0625	3/64	1/32
26883–26820	1.3779	3.1562	1.0000	1/32	1/8	4388–4335	1.6250	3.5625	1.5625	3/64	1/8
2794–2720	1.4365	3.0000	.9375	3/64	1/8	49162–49368	1.6250	3.6875	1.2500	3/64	1/8
19143–19283	1.4375	2.8345	.6700	1/16	1/16	46162–46368	1.6250	3.6875	1.2500	1/32	1/8
16143–16284	1.4375	2.8440	.8125	3/64	3/64	447–432	1.6250	3.7500	1.0938	3/64	3/32
3878–3820	1.4375	3.3750	1.1875	1/32	1/8	526–522	1.6250	4.0000	1.3750	3/64	1/8
13889–13836	1.5000	2.5625	.5000	1/16	1/32	25578–25520	1.6875	3.2650	.9375	.090	1/32
13685–13621	1.5000	2.7170	.7500	3/64	3/32	3579–3525	1.6875	3.4375	1.1875	3/64	1/8
19150–19283	1.5000	2.8345	.6700	.060	1/16	342S–332	1.6880	3.1496	.8268	3/64	3/64
16150–16284	1.5000	2.8440	.8125	3/64	3/64	26884–26820	1.6880	3.1562	1.0000	3/64	1/8
2788–2720	1.5000	3.0000	.9375	3/64	1/8	25577–25520	1.6880	3.2650	.9375	3/64	1/32
3490–3420	1.5000	3.1250	1.1563	3/64	1/8	12175–12303	1.7500	3.0312	.6875	.060	.060
28151–28315	1.5000	3.1495	.8270	3/64	1/16	13175–13318	1.7500	3.1875	.7500	0	1/16
337–332	1.5000	3.1496	.8268	1/32	3/64	35175–35326	1.7500	3.2650	.8750	3/64	1/32
3381–3320	1.5000	3.1562	1.1563	3/64	1/8	25580–25520	1.7500	3.2650	.9375	3/64	1/32
3876–3820	1.5000	3.3750	1.1875	3/64	1/8	355–354A	1.7500	3.3464	.8125	1/32	3/64
418–414	1.5000	3.4843	1.0625	3/64	1/32	3578–3525	1.7500	3.4375	1.1875	3/64	1/8
49150–49368	1.5000	3.6875	1.2500	3/64	1/8	49175–49368	1.7500	3.6875	1.2500	3/64	1/8

TABLE 19c—TAPER ROLLER BEARINGS—TYPE TS (*Continued*)

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.	Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
46176–46368	1.7500	3.6875	1.2500	9/64	1/8	529X–522	2.0000	4.0000	1.3750	9/64	1/8
438–432	1.7500	3.7500	1.0938	9/64	3/32	455–453X	2.0000	4.1250	1.1875	1/32	1/8
527–522	1.7500	4.0000	1.3750	9/64	1/8	59200–59412	2.0000	4.1250	1.4375	9/64	1/8
460–453X	1.7500	4.1250	1.1875	9/64	1/8	4580–4535	2.0000	4.1250	1.5625	9/64	1/8
59175–59412	1.7500	4.1250	1.4375	9/64	1/8	537–532X	2.0000	4.2500	1.4375	9/64	1/8
535–532X	1.7500	4.2500	1.4375	9/64	1/8	3975–3920	2.0000	4.4375	1.1875	9/64	1/8
65385–65321	1.7500	4.5000	1.7500	9/64	1/32	619–612	2.0000	4.7500	1.6250	9/64	1/8
615–612	1.7500	4.7500	1.6250	9/64	1/8	555–552A	2.0000	4.8750	1.5000	3/32	1/8
25584–25520	1.7710	3.2650	.9375	1/16	1/32	6279–6220	2.0000	5.000	2.0000	9/64	1/8
3776–3720	1.7710	3.6718	1.1875	9/64	1/8	3767–3720	2.0625	3.6718	1.1875	3/32	1/8
358–354A	1.7716	3.3464	.8125	1/16	3/64	33890–33821	2.0625	3.7500	1.0938	1/16	3/32
376–372A	1.7716	3.8125	.8750	1/32	1/16	377–372A	2.0625	3.8125	.8750	3/32	1/16
18690–18620	1.8125	3.1250	.6875	7/64	1/16	540–532X	2.0625	4.2500	1.4375	9/64	1/8
13181–13318	1.8125	3.1875	.7500	1/32	1/16	389A–382	2.1250	3.8750	.8268	1/32	1/32
359S–354A	1.8125	3.3464	.8125	3/32	3/64	456–453X	2.1250	4.1250	1.1875	9/64	1/8
2984–2924	1.8125	3.3464	1.0000	9/64	3/64	4595–4535	2.1250	4.1250	1.5625	9/64	1/8
436–432	1.8125	3.7500	1.0938	9/64	3/32	539–532X	2.1250	4.2500	1.4375	9/64	1/8
369A–362A	1.8750	3.5000	.8125	9/64	3/64	621–612	2.1250	4.7500	1.6250	9/64	1/8
3778–3720	1.8750	3.6718	1.1875	1/4	1/8	557S–552A	2.1250	4.8750	1.5000	9/64	1/8
528–522	1.8750	4.0000	1.3750	9/64	1/8	6280–6220	2.1250	5.0000	2.0000	9/64	1/8
5358–5335	1.8750	4.0625	1.7188	5/64	1/8	636–632	2.1250	5.3750	1.6250	9/64	1/8
463–453X	1.8750	4.1250	1.1875	5/16	1/8	385–382	2.1653	3.8750	.8268	3/32	1/32
536–532X	1.8750	4.2500	1.4375	9/64	1/8	389–382	2.1880	3.8750	.8268	3/32	1/32
617–612	1.8750	4.7500	1.6250	9/64	1/8	28682–28622	2.2500	3.8437	.9688	9/64	1/32
5395–5335	1.9375	4.0625	1.7188	9/64	1/8	387A–382	2.2500	3.8750	.8268	9/64	1/32
366–362A	1.9685	3.5000	.8125	3/32	3/64	462–453X	2.2500	4.1250	1.1875	5/64	1/8
465–453X	1.9685	4.1250	1.1875	3/32	1/8	390–394A	2.2500	4.3307	.8661	3/32	3/64
18200–18337	2.0000	3.3750	.7500	.060	.060	3979–3920	2.2500	4.4375	1.1875	9/64	1/8
368A–362A	2.0000	3.5000	.8125	9/64	3/64	623–612	2.2500	4.7500	1.6250	9/64	1/8
3780–3720	2.0000	3.6718	1.1875	9/64	1/8	555S–552A	2.2500	4.8750	1.5000	9/64	1/8
375–372A	2.0000	3.8125	.8750	3/32	1/16	65225–65500	2.2500	5.0000	1.7500	9/64	1/8
49585–49520	2.0000	4.0000	1.2500	9/64	1/8	6375–6320	2.2500	5.3447	2.1250	11/64	1/8

TABLE 19d—TAPER ROLLER BEARINGS—TYPE TS (*Continued*)

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.	Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
29582–29520	2.3622	4.2500	1.0000	1/32	1/8	567A–563	2.8125	5.0000	1.4375	9/64	1/8
397–394A	2.3622	4.3307	.8661	1/32	3/64	645–632	2.8125	5.3750	1.6250	1/4	1/8
28985–28920	2.3750	4.0000	1.0000	9/64	1/8	567–563	2.8750	5.0000	1.4375	9/64	1/8
3980–3920	2.3750	4.4375	1.1875	9/64	1/8	744–742	2.8750	5.9090	1.7500	9/64	1/8
6376–6320	2.3750	5.3447	2.1250	9/64	1/8	657–652	2.8750	6.0000	1.6250	9/64	1/8
39250–39412	2.5000	4.1250	.8438	.080	.080	568–563	2.9062	5.0000	1.4375	1/32	1/8
395–394A	2.5000	4.3307	.8661	9/64	3/64	34300–34478	3.0000	4.7812	.9688	.080	.080
3982–3920	2.5000	4.4375	1.1875	9/64	1/8	47680–47620	3.0000	5.2500	1.3125	1/32	1/8
33251–33462	2.5000	4.6250	1.1875	1/32	1/8	495A–493	3.0000	5.3750	1.1875	9/64	1/8
477–472A	2.5000	4.7244	1.1418	1/32	1/8	575–572	3.0000	5.5115	1.4375	9/64	1/8
5584–5535	2.5000	4.8125	1.7188	9/64	1/8	6461–6420	3.0000	5.8750	2.1250	9/64	1/8
559–552A	2.5000	4.8750	1.5000	9/64	1/8	748S–742	3.0000	5.9090	1.7500	9/64	1/8
565–563	2.5000	5.0000	1.4375	9/64	1/8	659–652	3.0000	6.0000	1.6250	9/64	1/8
639–632	2.5000	5.3750	1.6250	9/64	1/8	6576–6535	3.0000	6.3750	2.1250	9/64	1/8
6379–6320	2.5625	5.3447	2.1250	9/64	1/8	843–832	3.0000	6.6250	2.1250	1/4	1/8
395S–394A	2.6250	4.3307	.8661	9/64	3/64	34306–34478	3.0625	4.7812	.9688	9/64	.080
3984–3920	2.6250	4.4375	1.1875	9/64	1/8	47681–47620	3.1875	5.2500	1.3125	9/64	1/8
33262–33462	2.6250	4.6250	1.1875	9/64	1/8	496–493	3.1875	5.3750	1.1875	9/64	1/8
479–472A	2.6250	4.7244	1.1418	3/32	1/8	581–572	3.1875	5.5115	1.4375	9/64	1/8
560–552A	2.6250	4.8750	1.5000	9/64	1/8	740–742	3.1875	5.9090	1.7500	13/64	1/8
641–632	2.6250	5.3750	1.6250	9/64	1/8	838–832	3.1875	6.6250	2.1250	1/32	1/8
399A–394A	2.6875	4.3307	.8661	3/32	3/64	47686–47620	3.2500	5.2500	1.3125	9/64	1/8
480–472A	2.6875	4.7244	1.1418	9/64	1/8	495–493	3.2500	5.3750	1.1875	9/64	1/8
560S–552A	2.6875	4.8750	1.5000	9/64	1/8	580–572	3.2500	5.5115	1.4375	9/64	1/8
570–563	2.6875	5.0000	1.4375	9/64	1/8	663–652	3.2500	6.0000	1.6250	9/64	1/8
33275–33462	2.7500	4.6250	1.1875	9/64	1/8	842–832	3.2500	6.6250	2.1250	9/64	1/8
482–472A	2.7500	4.7244	1.1418	9/64	1/8	498–493	3.3125	5.3750	1.1875	9/64	1/8
566–563	2.7500	5.0000	1.4375	9/64	1/8	749–742	3.3475	5.9090	1.7500	9/64	1/8
643–632	2.7500	5.3750	1.6250	9/64	1/8	596–592A	3.3750	6.0000	1.5625	9/64	1/8
655–652	2.7500	6.0000	1.6250	9/64	1/8	665–652	3.3750	6.0000	1.6250	9/64	1/8
835–832	2.7500	6.6250	2.1250	9/64	1/8	593–592A	3.5000	6.0000	1.5625	9/64	1/8
33281–33462	2.8125	4.6250	1.1875	9/64	1/8	759–752	3.5000	6.3750	1.8750	9/64	1/8

TABLE 19e—TAPER ROLLER BEARINGS—TYPE TS (*Concluded*)

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.	Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
855–854	3.5000	7.5000	2.2500	5/16	1/8	797–792	5.1181	8.1250	1.8750	9/64	1/8
69354–69630	3.5430	6.3030	1.1860	3/32	1/8	67390–67320	5.2500	8.0000	1.8125	9/64	1/8
598–592A	3.6250	6.0000	1.5625	9/64	1/8	74525–74850	5.2500	8.5000	1.8750	9/64	1/8
77362–77675	3.6250	6.7500	1.8750	9/64	1/8	95525–95925	5.2500	9.2500	2.5000	3/8	1/8
42368–42584	3.6875	5.8437	1.1250	.120	.120	NA48390–48320	5.3750	7.5000	1.5625	9/64	1/8
42375–42584	3.7500	5.8437	1.1250	.120	.120						
						74537–74850	5.3750	8.5000	1.8750	9/64	1/8
594–592A	3.7500	6.0000	1.5625	9/64	1/8	EE580537–581200	5.3750	12.0000	3.1250	1/2	1/8
683–672	3.7500	6.6250	1.6250	9/64	1/8	74550–74850	5.5000	8.5000	1.8750	9/64	1/8
77375–77675	3.7500	6.7500	1.8750	9/64	1/8	73551–73875	5.5000	8.7500	1.3750	9/64	1/8
685–672	3.8750	6.6250	1.6250	9/64	1/8	898–892	5.5000	9.0000	2.2500	9/64	1/8
779–772	3.8750	7.1250	1.8750	9/64	1/8	82550–82950	5.5000	9.5000	2.2500	9/64	1/8
52400–52618	4.0000	6.1875	1.4375	9/64	1/8						
						99550–99100	5.5000	10.0000	2.6250	9/32	1/8
687–672	4.0000	6.6250	1.6250	9/64	1/8	EE540550–541162	5.5000	11.6250	3.2500	3/8	1/4
780–772	4.0000	7.1250	1.8750	9/64	1/8	EE750558–751200	5.5000	12.0000	2.3750	1/8	1/4
861–854	4.0000	7.5000	2.2500	5/16	1/8	EE450551–451212	5.5000	12.1250	3.5000	3/8	17/64
782–772	4.1250	7.1250	1.8750	9/64	1/8	73562–73875	5.6250	8.7500	1.3750	9/64	1/8
37425–37625	4.2500	6.2500	.9063	9/64	1/8	82562–82950	5.6250	9.5000	2.2500	9/64	1/8
64450–64700	4.5000	7.0000	1.6250	9/64	1/8						
						82576–82950	5.7500	9.5000	2.2500	9/64	1/8
71450–71750	4.5000	7.5000	1.8750	9/64	1/8	81575–81962	5.7500	9.6250	1.8750	9/64	1/8
938–932	4.5000	8.3750	2.6250	9/32	1/8	99575–99100	5.7500	10.0000	2.6250	9/32	1/8
68462–68712	4.6250	7.1250	1.3750	9/64	1/8	EE107057–107105	5.7500	10.5625	2.9375	1/4	1/4
795–792	4.7500	8.1250	1.8750	1/8	1/8	EE217056–217112	5.7500	11.2500	3.0000	1/4	1/4
67388–67320	5.0000	8.0000	1.8125	9/64	1/8	EE750576–751200	5.7500	12.0000	2.3750	3/8	1/4
74500–74850	5.0000	8.5000	1.8750	9/64	1/8						
						EE450577–451212	5.7500	12.1250	3.5000	3/8	17/64
95500—95925	5.0000	9.2500	2.5000	1/4	1/8	82587–82950	5.8750	9.5000	2.2500	9/64	1/8
EE116050–116097	5.0000	9.7500	2.5000	1/8	3/16	99587–99100	5.8750	10.0000	2.6250	9/32	1/8
EE153050–153100	5.0000	10.0000	3.0625	3/8	1/4	EE560590–561275	5.9000	12.7500	3.0625	17/32	3/16
EE540502–541162	5.0000	11.6250	3.2500	17/32	1/4	81600–81962	6.0000	9.6250	1.8750	9/64	1/8
EE455051–455116	5.0000	11.6250	3.3750	1/4	1/4	99600–99100	6.0000	10.0000	2.6250	9/32	1/8
EE580500–581200	5.0000	12.0000	3.1250	1/4	1/8						
						EE107060–107105	6.0000	10.5625	2.9375	1/4	1/4
EE750502–751200	5.0000	12.0000	2.3750	1/4	1/4	EE217060–217112	6.0000	11.2500	3.0000	1/16	1/4
48506–48750	5.0625	7.5000	1.3750	9/64	1/8	EE450601–451212	6.0000	12.1250	3.5000	3/8	17/64
799–792	5.0625	8.1250	1.8750	1/8	1/8	EE560600–561275	6.0000	12.7500	3.0625	11/16	3/16

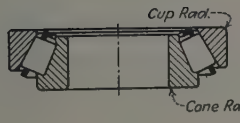
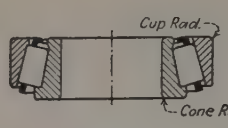
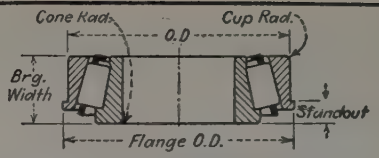


TABLE 20—TAPER ROLLER BEARINGS—TYPE TSS

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
11590–11520	0.6250	1.6875	0.5625	1/16	1/16
21075–21212	0.7500	2.1250	0.8750	1/16	3/32
23100–23256	1.0000	2.5625	0.8750	1/16	1/16
41100–41286	1.0000	2.8593	0.9688	3/32	1/16
41125–41286	1.1250	2.8593	0.9688	3/16	1/16
43112–43312	1.1250	3.1250	1.0000	1/32	1/16
43125–43312	1.2500	3.1250	1.0000	1/16	1/16
44150–44348	1.5000	3.4843	1.0000	3/32	1/16
44158–44348	1.5625	3.4843	1.0000	9/64	1/16
53162–53375	1.6250	3.7500	1.2188	1/16	1/32
53177–53375	1.7500	3.7500	1.2188	9/64	1/32
55200–55443	2.0000	4.4375	1.1875	9/64	1/8
72200–72487	2.0000	4.8750	1.4375	9/64	1/8
72212–72487	2.1250	4.8750	1.4375	9/64	1/8
78215–78551	2.1250	5.5130	1.4375	9/64	3/32
66585–66520	2.3622	4.8125	1.3125	9/64	1/8
9180–9121	2.4375	6.0000	1.8750	9/64	1/8
78250–78551	2.5000	5.5130	1.4375	3/32	3/32
9185–9121	2.6875	6.0000	1.8750	9/64	1/8
9285–9220	3.0000	6.3750	1.9375	9/64	1/8
9380–9321	3.0000	6.7500	1.9375	9/64	1/8
98316–98788	3.1496	7.8740	2.0772	9/64	1/8
9385–9321	3.3125	6.7500	1.9375	9/64	1/8
98335–98788	3.3465	7.8740	2.0772	9/64	1/8
98350–98788	3.5000	7.8740	2.0772	9/64	1/8
90381–90744	3.8125	7.4375	2.0000	9/64	1/8
98400–98788	4.0000	7.8740	2.0772	9/64	1/8
EE215040–215096	4.0000	9.8750	3.0000	1/4	1/8



(See Table 21.)



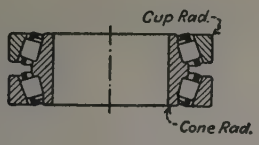
(See Table 22.)

TABLE 21—TAPER ROLLER BEARINGS—TYPE TST

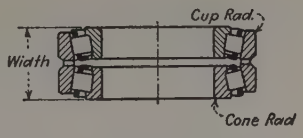
Bearing No.	Bore		Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
	Diam.	Taper per Ft.				
15575T–15520	0.9375	1.00	2.2500	0.6875	1/16	1/16
07098T–07204	0.9835	1.00	2.0470	0.5910	1/16	3/64
1757–1729	1.0000	1.00	2.2400	0.7625	1/32	3/64
2688T–2631	1.0625	1.00	2.6150	0.9375	1/16	3/64
26112T–26283	1.1250	1.00	2.8345	0.7480	1/16	1/16
26117T–26283	1.1770	1.00	2.8345	0.7480	1/16	1/16
2583T–2523	1.1875	1.00	2.7500	0.9375	1/16	3/64
14123T–14276	1.2500	1.00	2.7170	0.7813	1/16	3/64
2580T–2523	1.2500	1.00	2.7500	0.9375	1/16	3/64
14582T–14525	1.3125	1.00	2.6875	0.8125	1/32	3/32
2581T–2523	1.3125	1.00	2.7500	0.9375	1/32	3/64
14132T–14276	1.3125	1.00	2.7170	0.7813	1/16	3/64
2790T–2720	1.3125	1.00	3.0000	0.9375	1/32	1/16
25877T–25820	1.3750	1.00	2.8750	0.9375	1/16	3/32
2787–2720	1.3750	1.00	3.0000	0.9375	1/16	1/16
3379T–3320	1.3750	1.00	3.1562	1.1563	1/32	1/16
2791T–2720	1.4062	1.00	3.0000	0.9375	3/64	1/16
25879T–25820	1.4375	1.00	2.8750	0.9375	1/16	3/32
3380T–3320	1.4375	1.00	3.1562	1.1563	1/16	1/16
2798T–2720	1.4855	1.00	3.0000	0.9375	1/16	1/16
26876T–26820	1.4855	1.00	3.1562	1.0000	1/16	1/16
19150T–19283	1.5000	1.00	2.8345	0.6700	1/16	1/16
2882T–2820	1.5000	1.00	2.8750	0.8750	1/32	1/16
2788T–2720	1.5000	1.00	3.0000	0.9375	1/16	1/16
3490T–3420	1.5000	1.00	3.1250	1.1563	3/64	1/16
3381T–3320	1.5000	1.00	3.1562	1.1563	3/64	1/16
415T–414	1.5000	1.00	3.4843	1.0625	1/32	1/32
26879T–26820	1.5495	1.00	3.1562	1.0000	1/16	1/16
11156T–11315	1.5625	1.00	3.1495	0.7090	1/16	1/16
3382T–3320	1.5625	1.00	3.1562	1.1563	3/64	1/16
3575T–3525	1.5625	1.00	3.4375	1.1875	1/16	1/16
422T–414	1.5625	1.00	3.4843	1.0625	3/32	1/32
3384T–3320	1.6250	1.00	3.1562	1.1563	1/16	1/16
419T–414	1.6250	1.00	3.4843	1.0625	3/64	1/32
439T–432	1.6250	1.00	3.7500	1.0938	1/32	3/32
3578T–3525	1.7500	1.00	3.4375	1.1875	3/64	1/16
435T–432	1.7500	1.00	3.7500	1.0938	1/32	3/32
349T–332	1.7688	9°0′	3.1496	0.8268	1/32	3/64
25584T–25520	1.7708	1.00	3.2650	0.9375	1/16	1/32
359–354A	1.8125	1.00	3.3464	0.8125	1/32	3/64
463T–453X	1.8438	1.00	4.1250	1.1875	1/16	1/16
536T–532X	1.8750	1.00	4.2500	1.4375	3/64	1/16
537T–532X	2.0000	1.00	4.2500	1.4375	3/64	1/16
65199T–65500	2.0000	2.00	5.0000	1.7500	3/64	1/16
377T–372A	2.0625	1.00	3.8125	0.8750	1/32	1/16
28677T–28622	2.0625	1.00	3.8437	0.9688	3/64	1/32
368T–362A	2.0852	9°0′	3.5000	0.8125	1/32	3/64
539T–532X	2.1250	1.00	4.2500	1.4375	3/64	1/16
65212T–65500	2.1250	2.00	5.0000	1.7500	3/64	1/16
467T–453X	2.2500	1.00	4.1250	1.1875	3/64	1/16
468T–453X	2.3125	1.00	4.1250	1.1875	3/64	1/16
388T–382	2.3340	9°0′	3.8750	0.8268	1/32	1/32
559T–552A	2.5000	1.00	4.8750	1.5000	1/32	1/16
560T–552A	2.6250	1.50	4.8750	1.5000	3/64	1/16
399T–394A	2.6463	9°0′	4.3307	0.8661	1/32	3/64
485T–472A	2.8447	1.00	4.7244	1.1418	3/64	1/16
488T–472A	2.8773	9°0′	4.7244	1.1418	1/32	1/16
755T–752	3.0000	1.50	6.3750	1.8750	3/64	1/16
5784–5735	3.1875	1.00	5.3438	1.7500	3/64	1/16
758T–752	3.3750	1.00	6.3750	1.8750	3/64	1/16
764T–752	3.6250	1.00	6.3750	1.8750	3/64	1/16
52398T–52618	3.9838	9°0′	6.1875	1.4375	1/32	1/16
780T–772	4.0000	1.50	7.1250	1.8750	3/64	1/16

TABLE 22—TAPER ROLLER BEARINGS—TYPE TSF

Bearing No.	Bore	Outside Diam.	Flange O.D.	Stand Out	Bear. Width	Cone Rad.	Cup Rad.
A2047–A2126B	0.4720	1.2595	1.3845	.1753	0.3940	1/32	3/64
A4050–A4138B	0.5000	1.3775	1.5025	.1831	0.4330	3/64	3/64
A6062–A6157B	0.6250	1.5745	1.6995	.1918	0.4730	3/64	3/64
05075–05185B	0.7500	1.8504	2.0064	.2381	0.5662	3/64	1/16
21075–21212B	0.7500	2.1250	2.2812	.4063	0.8750	1/16	1/32
1380–1328B	0.8750	2.0625	2.2187	.3563	0.7625	1/16	1/16
1755–1729B	0.8750	2.2400	2.3960	.2938	0.7625	3/64	1/32
07093–07204B	0.9375	2.0470	2.2030	.2004	0.5910	1/16	1/16
1986–1931B	1.0000	2.3750	2.5310	.3125	0.7813	3/64	1/32
23100–23256B	1.0000	2.5625	2.7187	.4063	0.8750	1/16	1/16
41100–41286B	1.0000	2.8593	3.0781	.5000	0.9688	3/32	1/16
2689–2631B	1.1250	2.6150	2.7710	.3438	0.9375	3/64	1/32
17118–17244B	1.1805	2.4410	2.5970	.2075	0.6300	1/16	1/16
26118–26283B	1.1805	2.8345	2.9905	.2793	0.7480	1/16	1/16
3191–3120B	1.1875	2.8593	3.0473	.4375	1.1875	3/64	1/16
08125–08231B	1.2500	2.3125	2.4685	.2653	0.5781	.040	.040
02475–02420B	1.2500	2.6875	2.8437	.3438	0.8750	3/64	1/16
14125A–14276B	1.2500	2.7170	2.8730	.3125	0.7813	3/64	1/32
2582–2523B	1.2500	2.7500	2.9060	.3438	0.9375	3/64	1/16
3478–3420B	1.3750	3.1250	3.3130	.4063	1.1563	3/64	1/16
19138–19283B	1.3770	2.8345	2.9905	.2481	0.6700	1/16	1/16
16143–16284B	1.4375	2.8440	3.0000	.3438	0.8125	3/64	1/32
28151–28315B	1.5000	3.1495	3.3055	.3583	0.8270	3/64	1/16
3381–3320B	1.5000	3.1562	3.3436	.4063	1.1563	3/64	1/16
44150–44348B	1.5000	3.4843	3.7023	.5313	1.0000	1/32	1/16
26881–26822B	1.5625	3.1250	3.2812	.3438	0.9375	3/64	1/32
344–332B	1.5748	3.1496	3.3370	.3125	0.8268	3/64	1/32
3577–3525B	1.6250	3.4375	3.6255	.4375	1.1875	3/64	1/16
447–432B	1.6250	3.7500	3.9680	.4375	1.0938	3/64	1/32
355X–354B	1.7500	3.3464	3.5339	.3125	0.8125	3/64	1/16
53177–53387B	1.7500	3.8750	4.1250	.6563	1.2188	3/64	1/32
369A–362B	1.8750	3.5433	3.7308	.3499	0.7874	3/64	1/32
18200–18337B	2.0000	3.3750	3.5310	.3906	0.7500	.060	.060
3780–3720B	2.0000	3.6718	3.8598	.4375	1.1875	3/64	1/16
529X–522B	2.0000	4.0000	4.2500	.5625	1.3750	3/64	1/16
455S–453B	2.0000	4.2500	4.4680	.4375	1.0938	3/64	1/32
537–532B	2.0000	4.3750	4.6250	.5625	1.5000	3/64	1/16
619–612B	2.0000	4.7500	5.0312	.6563	1.6250	3/64	1/16
387A–382B	2.2500	3.8125	4.0000	.3125	0.8268	3/64	1/32
390–394AB	2.2500	4.3307	4.5187	.3125	0.8661	1/32	3/64
39250–39412B	2.5000	4.1250	4.3125	.4063	0.8438	.080	.080
29585–29520B	2.5000	4.2500	4.4062	.4063	1.0000	3/64	1/16
3982–3920B	2.5000	4.4375	4.6250	0.4375	1.1875	3/64	1/16
559–552B	2.5000	4.8750	5.1250	0.5625	1.5000	3/64	1/16
6382–6320B	2.5000	5.3447	5.6567	0.6875	2.1250	1 1/64	1/16
639–632B	2.5000	5.3750	5.6560	0.6563	1.6250	3/64	1/16
480–472B	2.6875	4.7244	4.9424	0.4375	1.1730	3/64	1/16
566–563B	2.7500	5.0000	5.2500	0.5625	1.4375	3/64	1/16
6484–6420B	2.7500	5.8750	6.1875	0.6875	2.1250	1/16	1/16
29685–29620B	2.8750	4.4375	4.5940	0.4063	1.0000	3/64	1/16
34301–34481B	3.0000	4.8125	5.0000	0.3125	0.9688	3/64	.080
575–572B	3.0000	5.5115	5.7615	0.5625	1.4375	3/64	1/16
748S–742B	3.0000	5.9090	6.2210	0.6250	1.7500	3/64	1/16
659–652B	3.0000	6.0000	6.2812	0.6563	1.6250	3/64	1/16
47681–47620B	3.1875	5.2500	5.4690	0.5000	1.3125	3/64	1/16
496–493B	3.1875	5.3750	5.5930	0.5313	1.1875	3/64	1/16
757–752B	3.2500	6.3750	6.6870	0.6875	1.8750	3/64	1/16
842–832B	3.2500	6.6250	7.0000	0.8750	2.1250	3/64	1/16
598–592B	3.6250	6.0000	6.2500	0.6250	1.5625	3/64	1/16
683–672B	3.7500	6.6250	6.9070	0.7188	1.6250	3/64	1/16
77375–77675B	3.7500	6.7500	7.0625	0.6875	1.8750	3/64	1/16
52387–52637B	3.8750	6.3750	6.6250	0.6563	1.4375	3/64	1/16
780–772B	4.0000	7.1250	7.4370	0.6875	1.8750	3/64	1/16
861–854B	4.0000	7.5000	7.8750	0.8750	2.2500	3/64	1/16



(*See Table 23.*)



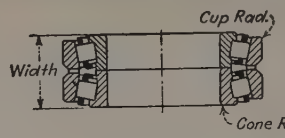
(*See Table 24.*)

TABLE 23—TAPER ROLLER BEARINGS—TYPE TDI

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
17116D–17244	1.1875	2.4410	1.3306	1/32	1/16
14126D–14276	1.2500	2.7170	1.5625	1/16	3/64
14134D–14276	1.3125	2.7170	1.5625	1/16	3/64
19145D–19283	1.4375	2.8345	1.5392	1/32	1/16
19152D–19283	1.5000	2.8345	1.5392	1/32	1/16
13169D–13318	1.6875	3.1875	1.3750	1/32	1/16
358D–354A	1.6875	3.3464	1.9790	1/16	3/64
13176D–13318	1.7500	3.1875	1.3750	0	1/16
13182D–13318	1.8125	3.1875	1.3750	1/32	1/16
376DE–372A	1.8750	3.8125	2.0940	1/32	1/16
378DE–372A	1.9375	3.8125	2.0940	1/32	1/16
375D–372A	2.0000	3.8125	2.0940	1/32	1/16
78216D–78551	2.1650	5.5130	2.6020	3/32	3/32
399D–394A	2.4375	4.3307	2.1870	1/32	3/64
78251D–78551	2.5000	5.5130	2.6020	3/32	3/32
765D–752	3.0000	6.3750	4.0000	9/64	1/8
496D–493	3.1875	5.3750	2.3750	1/16	1/8
581D–572	3.1875	5.5115	3.1875	1/16	1/8
498D–493	3.3125	5.3750	3.0000	1/32	1/8
767D–752	3.5000	6.3750	4.0000	1/16	1/8
865D–854	3.5000	7.5000	4.6250	3/8	1/8
42362D–42584	3.6250	5.8437	2.2500	1/16	120
867D–854	3.7500	7.5000	4.6250	1/4	1/8
52388D–52618	3.8750	6.1875	3.1563	1/16	1/8
779D–772	3.8750	7.1250	4.0000	1/16	1/8
52400D–52618	4.0000	6.1875	3.1563	1/16	1/8
868D–854	4.0000	7.5000	4.6250	1/16	1/8
945D–932	4.0000	8.3750	5.6250	13/32	1/8
782D–772	4.1250	7.1250	4.0000	1/16	1/8
71426D–71750	4.2500	7.5000	3.8750	1/16	1/8
946D–932	4.2500	8.3750	5.6250	1/8	1/8
95426D–95925	4.2500	9.2500	5.5000	33/64	1/8
71450D–71750	4.5000	7.5000	3.8750	1/16	1/8
938D–932	4.5000	8.3750	5.6250	1/8	1/8
95451D–95925	4.5000	9.2500	5.5000	33/64	1/8
EE116048–116098	4.6250	9.8750	6.0000	5/16	3/16
95474D–95925	4.7500	9.2500	5.5000	1/4	1/8
EE153047–153100	4.7500	10.0000	6.3750	1/2	1/4
EE153048–153100	4.8750	10.0000	6.3750	7/16	1/4
97500D–97900	5.0000	9.0000	6.3125	1/16	1/8
95499D–95925	5.0000	9.2500	5.5000	13/64	1/8
EE153053–153100	5.0000	10.0000	6.3750	1/8	1/4
EE540501–541162	5.0000	11.6250	5.8750	33/64	1/4
EE455050–455116	5.0000	11.6250	6.5000	17/32	1/4
74512D–74850	5.1250	8.5000	4.0000	1/16	1/8
73512D–73875	5.1250	8.7500	2.3850	9/64	1/8
67390D–67320	5.2500	8.0000	3.6250	1/16	1/8
EE455052–455116	5.2500	11.6250	6.5000	3/8	1/4
EE450531–451250	5.3110	12.5000	6.3750	17/32	17/64
EE455053–455116	5.3750	11.6250	6.5000	17/32	1/4
73550D–73875	5.5000	8.7500	2.3850	9/64	1/8
EE455048–455116	5.5000	11.6250	6.5000	1/8	1/4
EE450550–451250	5.5000	12.5000	6.3750	17/32	17/64
EE92558D–92988	5.5620	9.8750	4.3750	1/16	3/16
EE517056–517117	5.6250	11.7500	4.2500	1/8	1/8
EE517057–517117	5.6875	11.7500	4.2500	1/8	1/8
81576D–81962	5.7500	9.6250	3.4375	1/16	1/8
EE450575–451250	5.7500	12.5000	6.3750	17/32	17/64
99587D–99100	5.8750	10.0000	4.7500	1/16	1/8
81601D–81962	6.0000	9.2950	3.4375	1/16	1/8
99603D–99100	6.0000	10.0000	6.2500	1/16	1/8
EE517061–517117	6.0000	11.7500	4.2500	1/8	1/8
EE450600–451250	6.0000	12.5000	6.3750	3/8	17/64

TABLE 24—TAPER ROLLER BEARINGS—TYPE TDO

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
05075–05185D	0.7500	1.8504	1.2500	3/64	1/32
17118–17245D	1.1805	2.4410	1.5625	1/16	1/32
26118–26284D	1.1805	2.8338	1.6835	1/16	1/32
24118–24262D	1.1875	2.6150	1.7500	1/16	1/32
15118–15251D	1.1805	2.5000	1.8125	9/64	1/32
2580–2524D	1.2500	2.7500	2.6250	1/32	1/32
02877–02823D	1.3750	3.0000	1.8750	9/64	1/8
3482–3424D	1.3750	3.2500	2.6250	1/32	1/32
28150–28318D	1.5000	3.1510	1.8125	1/16	1/32
447–432D	1.6250	3.7500	2.4375	9/64	1/32
22168–22325D	1.6875	3.2500	1.7500	.090	1/32
355–353D	1.7500	3.5480	2.0000	3/32	1/32
369A–363D	1.8750	3.5433	1.9687	9/64	1/32
3775–3729D	2.0000	3.6718	2.5625	1/32	1/32
455–452D	2.0000	4.2500	2.5625	1/32	1/32
537–533D	2.0000	4.3750	3.1250	9/64	1/16
387–384D	2.2500	3.9370	2.0625	3/32	1/32
395–394D	2.5000	4.3307	2.0625	9/64	1/32
559–552D	2.5000	4.8750	3.1250	9/64	1/16
639–632D	2.5000	5.3750	3.7500	9/64	1/16
480–472D	2.6875	4.7244	2.5625	9/64	1/32
566–563D	2.7500	5.0000	3.1875	9/64	1/16
659–654D	3.0000	6.0000	3.7500	9/64	1/16
748S–742D	3.0000	6.1250	4.0000	9/64	1/16
755–752D	3.0000	6.3750	4.1250	9/64	1/16
496–493D	3.1875	5.3750	2.7500	9/64	1/32
581–572D	3.1875	5.5115	3.2500	9/64	1/32
842–834D	3.2500	6.7500	4.9375	9/64	1/32
598–592D	3.6250	6.0000	3.2500	9/64	1/32
683–672D	3.7500	6.6250	3.6250	9/64	1/32
780–774D	4.0000	7.1250	4.1250	9/64	1/16
861–854D	4.0000	7.5000	5.0000	5/16	1/16
936–932D	4.2500	8.3750	5.6250	5/16	1/16
64450–64700D	4.5000	7.0000	3.6250	9/64	1/32
71450–71751D	4.5000	7.5000	4.1875	9/64	1/16
795–792D	4.7500	8.1250	4.2500	1/8	1/32
67388–67322D	5.0000	7.7500	4.0000	9/64	1/32
74500–74851D	5.0000	8.5000	4.1875	9/64	1/16
95500–95927D	5.0000	9.2500	5.6250	1/4	1/16
82550–82932D	5.5000	9.3125	5.1875	9/64	1/16
EE750558–751204	5.5000	12.0000	5.3438	1/8	1/16
81575–81963D	5.7500	9.6250	4.2500	9/64	1/16
99575–99102D	5.7500	10.0000	5.8750	9/32	1/16
EE450601–451215	6.0000	12.1250	7.8750	3/8	3/64



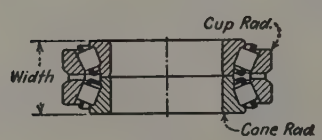
(*See Table 25.*)

TABLE 25—TAPER ROLLER BEARINGS—TYPE TNA

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.	Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
NA05075–05185D	0.7500	1.8504	1.2500	3/64	1/32	NA71450–71751D	4.5000	7.5000	4.1875	3/64	1/16
NA17098–17245D	0.9835	2.4410	1.5625	1/16	1/32	NA938–932D	4.5000	8.3750	5.6250	3/64	1/16
NA26118–26284D	1.1805	2.8338	1.6835	1/16	1/32	NA798–792D	5.0000	8.1250	4.2500	3/64	1/32
NA28138–28318D	1.3770	3.1510	1.8125	1/16	1/32	NA05500–05927D	5.0000	9.2500	5.6250	3/64	1/16
NA357–353D	1.5748	3.5480	2.0000	1/16	1/32	NA74525–74851D	5.2500	8.5000	4.1875	3/64	1/16
NA22171–22325D	1.7188	3.2500	1.7500	.090	1/32	NA48390–48320D	5.3750	7.5000	3.3750	3/64	1/32
NA438–432D	1.7500	3.7500	2.4375	3/64	1/32	NA81550–81963D	5.5000	9.6250	4.2500	3/64	1/16
NA366–363D	1.9685	3.5433	1.9688	3/64	1/32	NA82576–82932D	5.7500	9.3125	5.1875	3/64	1/16
NA3780–3729D	2.0000	3.6718	2.5625	3/64	1/32	NA82587–82932D	5.8750	9.3125	5.1875	3/64	1/16
NA455–452D	2.0000	4.2500	2.5625	3/64	1/32	NA81600–81963D	6.0000	9.6250	4.2500	3/64	1/16
NA539–533D	2.1250	4.3750	3.1250	3/64	1/16	NA99600–99102D	6.0000	10.0000	5.6250	3/64	1/16
NA385–384D	2.1653	3.9370	2.0625	3/64	1/32	NA94650–94114D	6.5000	11.3750	5.6250	3/64	1/16
NA397–394D	2.3622	4.3307	2.0625	3/64	1/32	NA67787–67720D	6.8750	9.7500	4.0625	3/64	1/32
NA476–472D	2.3622	4.7244	2.5625	3/64	1/32	NA67790–67720D	7.0000	9.7500	4.0625	3/64	1/32
NA558–552D	2.3750	4.8750	3.1250	3/64	1/16	NA87700–87112D	7.0000	11.1250	4.2500	3/64	1/16

TABLE 26—TAPER ROLLER BEARING TOLERANCE SPECIFICATIONS

	For Dimensions, In.	Tolerances				
		No. 0	No. 3	No. 2	No. 4C	No. 4B
Bore	Up to 2½ 2½ to 12	+.0005 to −.0 +.0005 to −.0	+.0005 to −.0 +.0005 to −.0	+.0005 to −.0 +.001 to −.0	+.0005 to −.0 +.001 to −.0	+.0005 to −.0 +.001 to −.0
Outside Diameter	Up to 12 12 to 24	+.0005 to −.0 ...	+.0005 to −.0 +.001 to −.0	+.001 to −.0 ...	+.001 to −.0 +.002 to −.0	+.001 to −.0 +.002 to −.0
Width	All	±.008	±.008	+.008 to −.0	+.003 to −.0	+.014 to −.010
Radii	All	+1/64 to −.0	+1/64 to −.0	+1/64 to −.0	+1/64 to −.0	+1/64 to −.0
Assembly Run-out	All	.00015	.0003	.0015	.002	.002



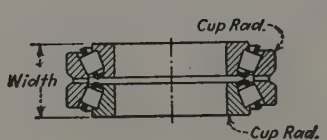


TABLE 27—TAPER ROLLER BEARINGS—TYPE TNAS

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
NA21075–21226D	0.7500	2.2500	1.9375	1/16	1/32
NA41125–41294D	1.1250	2.9375	2.1875	3/32	1/16
NA43131–43319D	1.3125	3.1875	2.1875	3/32	1/16
NA44156–44363D	1.5625	3.6250	2.1875	3/32	1/16
NA44163–44363D	1.6250	3.6250	2.1875	1/32	1/16
NA53176–53376D	1.7500	3.7500	2.5625	3/32	1/32
NA55200–55444D	2.0000	4.4375	2.5625	3/32	1/16
NA66212–66462D	2.1250	4.6250	2.8750	3/64	1/32
NA72212–72488D	2.1250	4.8750	3.0625	1/32	1/16
NA78250–78549D	2.5000	5.5000	3.0625	1/32	1/16
NA9378–9320D	3.0000	7.0000	4.3125	3/64	3/32
NA98350–98789D	3.5000	7.8750	4.5625	3/64	3/32

TABLE 28—TAPER ROLLER BEARINGS—TYPE TDOS

Bearing No.	Bore	Outside Diam.	Bearing Width	Cone Rad.	Cup Rad.
21075–21226D	0.7500	2.2500	1.9375	1/16	1/32
41100–41294D	1.0000	2.9375	2.1875	3/32	1/16
43125–43319D	1.2500	3.1875	2.1875	1/16	1/16
44150–44363D	1.5000	3.6250	2.1875	3/32	1/16
53176–53376D	1.7500	3.7500	2.5625	3/64	1/32
55200–55444D	2.0000	4.4375	2.5625	3/64	1/32
72200–72488D	2.0000	4.8750	3.0625	3/64	1/16
66212–66462D	2.1250	4.6250	2.8750	3/64	1/32
78250–78549D	2.5000	5.5000	3.0625	1/32	1/16
9385–9320D	3.3125	7.0000	4.3125	3/64	3/32
98335–98789D	3.3465	7.8750	4.5625	3/64	3/32

Ball Thrust Bearings

SAE Standard

Report of Ball and Roller Bearings Division approved August 1918 and last revised by Ball and Roller Bearings Technical Committee January 1949.

TABLE 29—ONE-DIRECTION (METRIC) BALL THRUST BEARINGS, TYPE TA

Bearing Number Type TA	Small Bore Diam., Nom.		Large Bore Diam., Min.		Outside Diam., Nom.		Height, Nom.		Fillet Rad. R[1] In.
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	
Light Series									
10TAO25	10	0.3937	10.2	0.4016	26	1.0236	12	0.4724	.02
12TAO25	12	0.4724	12.2	0.4803	28	1.1024	12	0.4724	.02
15TAO25	15	0.5906	15.2	0.5985	31	1.2205	12	0.4724	.02
18TAO25	18	0.7087	18.2	0.7166	35	1.3780	12	0.4724	.02
20TAO25	20	0.7874	20.2	0.7953	37	1.4567	12	0.4724	.02
25TAO25	25	0.9843	25.2	0.9922	45	1.7717	14	0.5512	.02
30TAO25	30	1.1811	30.2	1.1890	50	1.9685	14	0.5512	.02
35TAO25	35	1.3780	35.2	1.3859	55	2.1654	16	0.6299	.02
40TAO25	40	1.5748	40.2	1.5827	60	2.3622	16	0.6299	.02
45TAO25	45	1.7717	45.2	1.7796	68	2.6772	16	0.6299	.02
50TAO25	50	1.9685	50.2	1.9764	74	2.9134	18	0.7087	.02
55TAO25	55	2.1654	55.2	2.1733	78	3.0709	18	0.7087	.02
60TAO25	60	2.3622	60.2	2.3701	82	3.2284	18	0.7087	.02
65TAO25	65	2.5591	65.2	2.5670	90	3.5433	20	0.7874	.02
70TAO25	70	2.7559	70.2	2.7638	95	3.7402	20	0.7874	.02
75TAO25	75	2.9528	75.2	2.9607	100	3.9370	20	0.7874	.02
80TAO25	80	3.1496	80.2	3.1575	110	4.3307	22	0.8661	.02
85TAO25	85	3.3465	85.2	3.3544	115	4.5276	22	0.8661	.02
90TA11	90	3.5433	90.2	3.5512	120	4.7244	22	0.8661	.02
95TAO25	95	3.7402	95.2	3.7481	130	5.1181	25	0.9843	.02
100TA11	100	3.9370	100.2	3.9449	135	5.3150	25	0.9843	.02
105TAO25	105	4.1339	105.2	4.1418	140	5.5118	25	0.9843	.02
110TA11	110	4.3307	110.2	4.3386	145	5.7087	25	0.9843	.02
115TAO25	115	4.5276	115.2	4.5355	150	5.9055	25	0.9843	.02
120TAO25	120	4.7244	120.2	4.7323	160	6.2992	27	1.0630	.02
125TAO25	125	4.9213	125.2	4.9292	165	6.4961	27	1.0630	.02
Medium Series									
10TAO26	10	0.3937	10.2	0.4016	30	1.1811	12	0.4724	.02
15TAO26	15	0.5906	15.2	0.5985	35	1.3780	14	0.5512	.02
20TA12	20	0.7874	20.2	0.7953	40	1.5748	14	0.5512	.02
25TAO26	25	0.9843	25.2	0.9922	48	1.8898	15.5	0.6103	.02
30TAO26	30	1.1811	30.2	1.1890	53	2.0866	15.5	0.6103	.02
35TA12	35	1.3780	35.2	1.3859	62	2.4409	18	0.7087	.02
40TAO26	40	1.5748	40.2	1.5827	64	2.5197	18	0.7087	.02
45TAO26	45	1.7717	45.2	1.7796	73	2.8740	22	0.8661	.02
50TA12	50	1.9685	50.2	1.9764	78	3.0709	22	0.8661	.02
55TAO26	55	2.1654	55.2	2.1733	88	3.4646	24.5	0.9646	.02
60TAO26	60	2.3622	60.2	2.3701	90	3.5433	24.5	0.9646	.02
65TA12	65	2.5591	65.2	2.5670	100	3.9370	27	1.0630	.04
70TAO26	70	2.7559	70.2	2.7638	103	4.0551	27	1.0630	.04
75TA12	75	2.9528	75.2	2.9607	110	4.3307	27	1.0630	.04
80TAO26	80	3.1496	80.2	3.1575	115	4.5276	29	1.1417	.04
85TAO26	85	3.3465	85.2	3.3544	125	4.9213	30.5	1.2008	.04
90TAO26	90	3.5433	90.2	3.5512	135	5.3150	30.5	1.2008	.04
95TAO26	95	3.7402	95.2	3.7481	140	5.5118	32.5	1.2795	.04
100TAO26	100	3.9370	100.2	3.9449	150	5.9055	32.5	1.2795	.04
105TAO26	105	4.1339	105.2	4.1418	155	6.1024	40	1.5748	.04
115TAO26	115	4.5276	115.2	4.5355	165	6.4961	43	1.6929	.04
125TAO26	125	4.9213	125.2	4.9292	175	6.8898	46.5	1.8307	.04
140TAO26	140	5.5118	140.2	5.5197	200	7.8740	52	2.0472	.04

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the table. This specification does not control bearing corner contours.

(*Continued on next page.*)

TABLE 30a—ONE-DIRECTION (INCH) BALL THRUST BEARINGS, TYPE TB

Extra Light Series—Bores of both rings are the same.

Bearing Number Type TB	Bore Diam., In. Nominal	Outside Diam., In. Nominal	Height, In. Nominal	Fillet Rad. R[1] In.
8TBO30	1/2	1 7/32	9/16	.030
9TBO30	9/16	1 7/32	9/16	.030
10TBO30	5/8	1 11/32	9/16	.030
11TBO30	11/16	1 11/32	9/16	.030
12TBO30	3/4	1 15/32	9/16	.030
13TBO30	13/16	1 15/32	9/16	.030
14TBO30	7/8	1 27/32	5/8	.030
15TBO30	15/16	1 27/32	5/8	.030
16TBO30	1	1 31/32	5/8	.030
17TBO30	1 1/16	1 31/32	5/8	.030
18TBO30	1 1/8	2 3/32	5/8	.030
19TBO30	1 3/16	2 3/32	5/8	.030
20TBO30	1 1/4	2 11/32	5/8	.030
21TBO30	1 5/16	2 11/32	5/8	.030
22TBO30	1 3/8	2 15/32	5/8	.030
23TBO30	1 7/16	2 15/32	5/8	.030
24TBO30	1 1/2	2 19/32	5/8	.040
25TBO30	1 9/16	2 19/32	5/8	.040
26TBO30	1 5/8	2 31/32	13/16	.040
27TBO30	1 11/16	2 31/32	13/16	.040
28TBO30	1 3/4	3 3/32	13/16	.040
29TBO30	1 13/16	3 3/32	13/16	.040
30TBO30	1 7/8	3 7/32	13/16	.040
31TBO30	1 15/16	3 7/32	13/16	.040
32TBO30	2	3 11/32	13/16	.040
33TBO30	2 1/16	3 11/32	13/16	.060
34TBO30	2 1/8	3 15/32	13/16	.060
35TBO30	2 3/16	3 15/32	13/16	.060
36TBO30	2 1/4	3 23/32	13/16	.060
37TBO30	2 5/16	3 23/32	13/16	.060
38TBO30	2 3/8	3 27/32	13/16	.060
39TBO30	2 7/16	3 27/32	13/16	.060
40TBO30	2 1/2	3 31/32	13/16	.060
41TBO30	2 9/16	3 31/32	13/16	.060
42TBO30	2 5/8	4 1/32	1	.060
43TBO30	2 11/16	4 1/32	1	.060
44TBO30	2 3/4	4 15/32	1	.060
45TBO30	2 13/16	4 15/32	1	.060
46TBO30	2 7/8	4 19/32	1	.060
47TBO30	2 15/16	4 19/32	1	.080
48TBO30	3	4 23/32	1	.080
52TBO30	3 1/4	4 31/32	1	.080
56TBO30	3 1/2	5 1/32	1	.080

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the tables. This specification does not control bearing corner contours.

TABLE 30b—ONE-DIRECTION (INCH) BALL THRUST BEARINGS, TYPE TB

Medium Series—Bores of both rings are the same.

Type TB	Bore Diam., In. Nominal	Outside Diam., In. Nominal	Height, In. Nominal	Fillet Rad. R[1] In.
8TBO32	1/2	1 7/16	5/8	.030
9TBO32	9/16	1 7/16	5/8	.030
10TBO32	5/8	1 9/16	5/8	.030
11TBO32	11/16	1 9/16	5/8	.030
12TBO32	3/4	1 11/16	5/8	.030
13TBO32	13/16	1 11/16	5/8	.030
14TBO32	7/8	1 15/16	3/4	.030
15TBO32	15/16	1 15/16	3/4	.030
16TBO32	1	2 1/16	3/4	.030
17TBO32	1 1/16	2 1/16	3/4	.030
18TBO32	1 1/8	2 3/16	3/4	.030
19TBO32	1 3/16	2 3/16	3/4	.030
20TBO32	1 1/4	2 5/16	3/4	.030
21TBO32	1 5/16	2 3/16	3/4	.030
22TBO32	1 3/8	2 7/16	3/4	.030
23TBO32	1 7/16	2 7/16	3/4	.030
24TBO32	1 1/2	2 9/16	3/4	.040
25TBO32	1 9/16	2 9/16	3/4	.040
26TBO32	1 5/8	2 13/16	7/8	.040
27TBO32	1 11/16	2 13/16	7/8	.040
28TBO32	1 3/4	2 15/16	7/8	.040
29TBO32	1 13/16	2 13/16	7/8	.040
30TBO32	1 7/8	3 1/16	7/8	.040
31TBO32	1 15/16	3 1/16	7/8	.040
32TBO32	2	3 1/16	7/8	.040
33TBO32	2 1/16	3 3/16	7/8	.060
34TBO32	2 1/8	3 3/16	7/8	.060
35TBO32	2 3/16	3 3/16	7/8	.060
36TBO32	2 1/4	3 7/16	7/8	.060
37TBO32	2 5/16	3 7/16	7/8	.060
38TBO32	2 3/8	3 3/16	7/8	.060
39TBO32	2 7/16	3 3/16	7/8	.060
40TBO32	2 1/2	4	1 1/8	.060
41TBO32	2 9/16	4	1 1/8	.060
42TBO32	2 5/8	4 1/8	1 1/8	.060
43TBO32	2 11/16	4 1/8	1 1/8	.060

[1] The corner radius or chamfer on bearings must clear the maximum fillet radius given in the tables. This specification does not control bearing corner contours.

Helical Compression Springs Hot-Coiled for General Automotive Use

SAE Recommended Practice

Report of Spring Technical Committee approved September 1949 and last revised October 1950.

[*The following Recommended Practice deals with hot-coiled springs made from round steel bars of 3/8-in. or larger diameter. The ends of such springs are closed and squared, the bar ends being usually forged or taper rolled. The Recommended Practice furnishes a system of dimensional tolerances which serves to inform the user of practical manufacturer limits. Closer tolerances are obtainable where the accuracy is required and the increased cost is justified. Helical springs for motor vehicle suspension are covered in a separate Recommended Practice.*]

Definitions—All spring heights are measured after the spring has been deflected to its solid height to remove temporary recovery of free height.

Solid height is the perpendicular distance between the plates of the testing machine when the spring is compressed with an applied load sufficient to bring all coils in contact. However, in no case shall the applied load exceed by more than 50% the load beyond which no appreciable deflection takes place.

Free height is determined by placing a straightedge across the top of the spring and measuring the perpendicular distance from the plate on which the spring stands to the straightedge at the approximate center of the spring.

Loaded height is the perpendicular distance between the plates of the testing machine when the specified load has been applied.

Load is the force in pounds measured on the testing machine required to deflect the spring to the specified loaded height.

Rate, where considered important, is the average load per inch deflection, taken between approximately 20 and 60% of total deflection, unless otherwise defined.

Nominal solid load is the product of rate and total deflection. As it is the theoretical maximum load, it may be used for computing the corresponding stress. The solid load obtained by test should not be used in calculations, as it is usually different from the nominal figure.

Permanent set is the loss of free height after the spring has been compressed solid three times with the applied load specified under solid height determination, measured at the same point and in the same manner.

Tolerances

Diameter of Bar Stock—Tolerances for diameters of bar stock are given in Table 1.

TABLE 1—*Tolerances for Diameter of Bar Stock*

BAR DIAMETER, IN.	TOLERANCE, IN., PLUS OR MINUS
Over 5/16 to 7/16 inclusive	0.006
Over 7/16 to 5/8 inclusive	0.007
Over 5/8 to 7/8 inclusive	0.008
Over 7/8 to 1 inclusive	0.009
Over 1 to 1 1/8 inclusive	0.010
Over 1 1/8 to 1 1/4 inclusive	0.011
Over 1 1/4 to 1 3/8 inclusive	0.012
Over 1 3/8 to 1 1/2 inclusive	0.014
Over 1 1/2 to 2 inclusive	0.016

Coil Diameter—Tolerances for coil diameters are given in Table 2.

TABLE 2—*Tolerances for Coil Diameters*

FOR SPECIFIED OR COMPUTED OUTSIDE DIAMETER, IN.	INSIDE OR OUTSIDE DIAMETER TOLERANCE, IN., PLUS OR MINUS				
	For free spring height				
	Up to 10 inclusive	Over 10 to 18 incl.	Over 18 to 26 incl.	Over 26 to 34 incl.	Over 34 to 42 incl.
Up to 6 inclusive	1/16	3/32	1/8	5/32	3/16
Over 6 to 8 inclusive	3/32	1/8	3/16	1/4	1/4
Over 8 to 12 inclusive	1/8	3/16	1/4	1/4	1/4

Free Height—If load is specified, free height should read "approximate" only, and not be restricted by any tolerance.

If load is not specified: free height tolerance = ±(1/16 in. + 4% of total deflection)

Loaded Height—Variation in loaded height with load fixed is: Loaded height tolerance = ±(1/16 in. + 3% of total deflection)

Variation in load with loaded height fixed is: Load tolerance = ±(1/16 in. + 3% of total deflection) × rate

The foregoing height tolerances are limited to springs with free height not over 36 in., not over six times total deflection, and not less than 0.8 times outside diameter. Tolerances for springs outside these limits are considered special.

Solid Height and Total Number of Coils—Maximum solid height (as tested) or nominal solid height (as computed) may be specified on the drawing. Nominal solid height is computed as total number of coils minus one half coil, multiplied by wire diameter.

The total number of coils shall not vary more than 5% from the number specified or indicated by the formula in the preceding sentence.

When nominal solid height is specified, the tolerances given in Table 3 apply.

TABLE 3—*Maximum Solid Height above Nominal Solid Height*

NOMINAL SOLID HEIGHT, IN.	MAXIMUM SOLID HEIGHT ABOVE NOMINAL HEIGHT, IN.
Up to 7 inclusive	1/16
Over 7 to 10 inclusive	3/32
Over 10 to 13 inclusive	1/8
Over 13 to 16 inclusive	5/32
Over 16 to 19 inclusive	3/16
Over 19 to 22 inclusive	7/32
Over 22 to 25 inclusive	1/4

Uniformity of Pitch—The pitch of the coils shall be sufficiently uniform so that when the spring is compressed, unsupported laterally, to a height representing a deflection of 80% of the nominal total deflection, none of the coils shall be in contact with another, excluding the inactive end coils.

When the design of the spring is such that it cannot be com-

pressed to solid height without lateral support, the above requirement does not apply.

Permanent Set—Permanent set shall not exceed $\frac{1}{32}$ in. + ½% of total deflection.

Squareness of Ends—The ends of the bar shall be tapered to give the finished spring a reasonably firm bearing. The tip of the tapered bar shall be in approximate contact with the adjacent coil and shall not protrude more than ⅛ in. beyond the outside diameter of the spring.

Unless otherwise specified, the ends of any spring having an outside diameter to bar diameter ratio of 4 or more, and a free height to outside diameter ratio of 4 or less, shall not deviate more than 3 deg from the perpendicular to the spring axis, as determined by standing the spring on its end and measuring the angular deviation of the outer helix from a perpendicular to the plate on which the spring is standing.

When stipulated, the end bearing surfaces of the springs shall be ground to produce a firm bearing. The actual ground bearing surface shall not be shorter than two-thirds of the mean coil circumference, nor narrower than half the width of the hot-tapered surface of the bar.

Helical Compression and Extension Springs Cold-Coiled for General Automotive Use

SAE Recommended Practice

Report of Spring Technical Committee approved September 1949.

[*The following recommended practice deals with cold-coiled springs made from round steel wire of ⅜ in. or smaller diameter. It furnishes a system of dimensional tolerances for springs of average quality as used for the majority of automotive applications. Springs can be made to closer tolerances at an increased cost; valve springs are a typical example. Again, springs can be made cheaper by omitting some tolerances.*]

Tolerances

Coil Diameter—Coil diameter tolerances can be specified on either the inside diameter or the outside diameter of the coils, depending upon the importance of the respective dimensions to the user. The tolerances to apply are functions of the ratio of mean diameter D of the coils to wire diameter d as given in Table 1. The tolerances are to be considered as manufacturing tolerances and do not take into account the effects of changes i diameter due to applied loads.

Free Length—When load with tolerance is not specified, it is advisable to specify the free length with tolerance. In the case of compression springs the free length is an overall dimension measured parallel to the axis of the spring; for extension springs the free length refers to the length inside to inside of the hooks (overall length minus two wire thicknesses). The tolerances to apply are functions of the ratio of mean diameter D of the coils to wire diameter d as given in Table 2.

These tolerances apply to compression springs and to open-coiled extension springs. For close-coiled extension springs with initial tension, the free-length tolerance is half of the value given in the right-hand column, regardless of D/d ratio.

Solid Height—If the spring is to be compressed nearly solid,

TABLE 1—*Coil Diameter Tolerances*

MEAN COIL DIAMETER, IN.	DIAMETER TOLERANCE, IN., PLUS OR MINUS	
	For D/d ratio	
	3 to 7.9	8 to 15
⅛ or less	0.003	0.004
Over ⅛ to ¼ inclusive	0.004	0.006
Over ¼ to ½ inclusive	0.006	0.010
Over ½ to 1 inclusive	0.010	0.016
Over 1 to 2 inclusive	0.016	0.025
Over 2 to 4 inclusive	0.025	0.042
Over 4 to 8 inclusive	0.042	0.063

TABLE 2—*Free Length Tolerances*

FREE LENGTH, IN.	TOLERANCE, IN., PLUS OR MINUS	
	For D/d ratio	
	3 to 7.9	8 to 15
½ or less	0.025	0.040
Over ½ to 1 inclusive	0.035	0.060
Over 1 to 2 inclusive	0.050	0.080
Over 2 to 4 inclusive	0.080	0.12
Over 4 to 8 inclusive	0.12	0.19
Over 8 to 16 inclusive	0.22	0.30
Over 16 to 32 inclusive	0.35	0.45

the solid height should be specified as a maximum dimension without tolerance.

Wire Diameter—Table 3 gives the tolerances for the various types of wire.

Load and Rate—Table 4 gives load and rate tolerances.

TABLE 3—*Wire Diameter Tolerances*

TYPE OF WIRE	WIRE DIAMETER, IN.	TOLERANCE, IN., PLUS OR MINUS
Music wire	up to 0.026 inclusive	0.0003
	0.027 to 0.063 inclusive	0.0005
	0.064 to 0.250 inclusive	0.001
Carbon steel wire hard drawn or oil tempered	up to 0.075 inclusive	0.001
	0.076 to 0.375 inclusive	0.002
	0.376 and larger	0.003
Valve - spring quality alloy steel wire	up to 0.148 inclusive	0.001
	0.149 to 0.177 inclusive	0.0015
	0.178 to 0.375 inclusive	0.002
	0.376 and larger	0.003

TABLE 4—*Load and Rate*[a] *Tolerances*

NUMBER OF ACTIVE COILS	LOAD TOLERANCE, %, PLUS OR MINUS	RATE TOLERANCE, %, PLUS OR MINUS
3 or less	15	10
Over 3 to 9 inclusive	10	8
Over 9 to 15 inclusive	8	6
Over 15	7	5

[a] The rate shall be determined between 20 and 60% of the total deflection obtained without exceeding the elastic limit of the spring.

Number of Coils—In order to meet the requirements on load, rate, free length, solid height, and position of end hooks, it is often necessary to vary the number of coils by ±10% for extension springs and by ±5% for compression springs. Therefore, the number of coils should be specified as an approximate figure for reference only.

Squareness of Ends—The squareness of the ends of squared and ground compression springs as measured in the unloaded position is to be maintained within a limit of 3 deg with the axis of the spring.

Helical Springs for Motor-Vehicle Suspension

SAE Recommended Practice

Report of Passenger Car Division approved January 1938 and last revised by Spring Technical Committee February 1948.

[*This Recommended Practice deals with helical compression springs made from alloy steel bars which are coiled hot and are heat-treated after coiling.*

The scope of this Recommended Practice is restricted to a concise presentation of items which will promote an adequate understanding between spring maker and spring user of the major practical requirements in the finished spring.]

Bar Tolerances and Surface Treatment—The bars required for these springs are usually ½ to ⅞ in. in diameter. It is customary to specify the diameter as the decimal dimension which works out most advantageously for purposes of design. The bars are either centerless ground (diameter tolerance ±0.002 in.) or precision hot rolled (diameter tolerance ±0.004 in.).

The bars are commonly purchased in the exact length required to produce one spring. The lengths vary in practice from 10 to 15 ft and are subject to a tolerance of ±⅛ in.

After heat-treatment, but before presetting, the springs are shot peened in a manner to assure adequate shot impingement intensity and coverage for optimum fatigue life. In order to retard corrosion, it is customary to apply an enamel finish to the springs.

Coil Diameters and Tolerances—For purposes of dimensional control it is customary to specify the coil diameters of these springs in terms of the inside diameter. In general, the inside diameters vary from 3 to 6 in., and tolerances to apply are ±1/32 in. for springs up to and including 4½ in. inside diameter, and ±3/64 in. for springs above 4½ in. inside diameter.

Types of Spring Ends—Three types of ends are used:

1. A flat end formed from a tapered bar end. Grinding of the outboard bearing surface is not required if the tapering and coiling are performed properly.

2. An untapered end coil formed substantially smaller in diameter than the central coils of the spring and in such fashion to have an outboard bearing surface perpendicular to the axis of the helix of the spring, the so-called "pig-tail" end.

3. An untapered end coil formed as a helix having a pitch substantially equal to the bar diameter. To facilitate coiling, a straight end portion about 1 in. long is permitted to project tangent to the helix of this end construction, the so-called

"tangent-tail" end. The use of this type of end requires a spring seat formed at the same pitch of helix as that of the spring end.

It is customary for springs to have any combination of the three types of ends except that of two tangent-tail ends, which combination involves a complex arrangement for the spring seats. Spring seats and ends are usually so formed as to render approximately two-thirds to one coil inactive at each end.

Definitions, Dimensions, and Tolerances—Load and rate are the terms usually employed to describe the capacity of a suspension coil spring. They are to be measured in terms of the forces exerted by the spring during compression of the spring (compression loads), and not during release of the spring (release loads).

Load is the force in pounds measured on the testing machine required to deflect the spring to the specified loaded height. Existing tolerances are from $\pm 1/16$ to $\pm 3/16$ of the nominal rate, depending upon the nature of the installation.

Rate is half the difference between the loads measured 1 in. above and 1 in. below the specified loaded height. Tolerance is $\pm 3\%$ with centerless-ground bars and $\pm 4\%$ with precision-rolled bars.

Spring heights are measured after preloading, as the distance parallel to the spring axis between two reference points specified on the spring drawing.

Loaded height is the distance between the two reference points while the load is being measured. It is a fixed reference dimension; tolerance is expressed in terms of load.

Free height is the distance between the two reference points under no load. It is used as an approximate dimension only.

Solid height is the distance between the two reference points when the spring is compressed under a load corresponding to approximately 150% of the load beyond which no appreciable deflection takes place.

Preloading is the operation of deflecting the spring to the solid height to remove temporary recovery before the spring is checked for load or rate. If the spring is designed to preclude deflection to the solid height by reason of excessive stresses, the drawing may specify that the preloading be confined to deflecting the spring at least to the metal-to-metal position defined under "Clearance." After preloading and before load and rate checking, the spring shall be released to the free height.

Clearance is the spring deflection possible in the vehicle from the specified loaded height to the spring height attained at the metal-to-metal contact position disregarding rubber bumpers.

Spring Specifications—Spring drawings or specifications should regard the following items as mandatory requirements:

Bar diameter and tolerance.
Inside diameter and tolerance.
Loaded height as a fixed reference dimension.
Load and tolerance.
Rate and tolerance.
Type ends.
Material.
Hardness range.
Surface treatment and finish.

It is helpful to include in the specifications the following items for purposes of guidance:

Approximate free height.
Bar length and tolerance.
Total number of coils.
Height at metal-to-metal contact position.
Solid height.

Leaf Springs for Motor-Vehicle Suspension

SAE Standard

Report of Springs Division approved August 1915 and last revised by Spring Technical Committee February 1948.

[*This SAE Standard is limited to a concise presentation of specifications which will promote an adequate understanding between spring maker and spring user on all practical requirements in the finished spring. Basic concepts of spring design are dealt with in SP-7, "Manual on Design and Application of Leaf Springs." This SAE Standard refers readers to the Manual in many instances for more thorough explanations. The Manual is available from the SAE Special Publications Department. Price: $2.00 to members, $4.00 to nonmembers.*]

Leaf Sections—Round-edge flat spring steel has been adopted as the SAE standard. However, special leaf sections such as the grooved and the parabolic-edge sections are also in wide use. (See Section 7 of SAE "Manual on Design and Application of Leaf Springs.") More detailed information may be obtained from the leaf-spring manufacturers or the vehicle manufacturers who use these special leaf sections.

Leaf Sizes and Rolling Tolerances—Spring drawings shall call for steel of the following specified nominal thicknesses in inches, to which all bars shall be rolled:

0.132	0.194	0.291	0.447	0.702	1.127
0.145	0.214	0.323	0.499	0.788	1.273
0.160	0.237	0.360	0.558	0.887	1.440
0.176	0.262	0.401	0.625	0.999	

The bars shall be of flat rolled steel having two flat surfaces and two rounded (convex) edges. The flatness tolerance permits

TABLE 1—*Desirable Cross-Section Tolerances*

NOMINAL WIDTH, IN.		WIDTH, IN.	THICKNESS[a] TOLERANCE, IN.			FLATNESS[b] TOLERANCE, IN.			MAXIMUM DIFFERENCE[c] IN THICKNESS, IN.		
			For thickness			For thickness			For thickness		
Over	To and including	Minus 0	0.375 or under	Over 0.375 to 0.875 inclusive	Over 0.875 to 1.500 inclusive	0.375 or under Plus 0	Over 0.375 to 0.875 inclusive Plus 0	Over 0.875 to 1,500 inclusive Plus 0	0.375 or under	Over 0.375 to 0.875 inclusive	Over 0.875 to 1.500 inclusive
0	2½	+0.030	±0.004	±0.006	—	−0.004	−0.006	—	0.002	0.002	—
2½	4	+0.050	±0.005	±0.008	±0.012	−0.005	−0.008	−0.012	0.003	0.004	0.006
4	5	+0.065	±0.006	±0.010	±0.016	−0.006	−0.010	−0.016	0.003	0.005	0.008
5	6	+0.080	—	±0.012	±0.020	—	−0.012	−0.220	—	0.006	0.010

[a] Thickness measurements shall be taken at the edge of the bar where the flat surfaces intersect the rounded edge.
[b] Flatness represents the difference between the thickness at the center of the bar and the thickness at the edges. A minus tolerance indicates a concave cross-section.
[c] Maximum difference in thickness between the two edges of each bar.

the two flat surfaces to be slightly concave. When that occurs, the radii of the arcs of the two concave surfaces shall be of approximately equal lengths.

The radii of the rounded edges shall be approximately equal to the thickness of the bar.

Bars shall be substantially straight and free from lateral kinks, waves, twists, or other imperfections which render them unsatisfactory for spring manufacturing purposes. Maximum lateral curvature shall be not more than ½ in. in 20 ft.

Definitions, Dimensions, and Tolerances—*Leaf Spring*—Laminated steel spring usually of semi-elliptic type, heat-treated after forming. The leaves are usually held together by a center bolt and are prevented from lateral shifting by clips.

Datum Line—Reference line used with many of the subsequently defined terms. On Fig. 1 it is shown as the line X—X. On springs with eyes, the datum line passes through the centers of the eyes. On other springs it passes through the points where the load is applied near the ends of the spring. These points must be indicated on the drawing. When load and rate are checked, the spring ends shall be free to move in the direction of the datum line.

Loaded Length—Distance between spring eye centers when the spring is deflected to the specified load position. On springs without eyes, it is the distance between the lines where load is applied under the specified conditions. Tolerance, ±⅛ in.

Loaded Fixed End Length—Distance from the center of the fixed eye to the projection on the datum line of the point where the centerline of the center bolt intersects the spring surface in contact with the spring seat. Tolerance, ±1/16 in.

Straight Length—Distance between spring eye centers when the main leaf is flat. Tolerance, ±⅛ in.

Seat Length—Portion of the spring rendered inactive through clamping and located on the side in direct contact with the spring seat on the vehicle.

Clamp Length—Portion of the spring rendered inactive through clamping and located on the side opposite the spring seat.

Seat Angle—Angle between the tangent to the center of the spring seat and the datum line. Tolerance, ±½ deg.

Nominal Width—Springs are commonly specified in the following widths: 1½, 1¾, 2, 2¼, 2½, 3, 3½, 4, 5, and 6 in.

Finished Width—Width to which the spring ends are finished to bring about flat bearing surfaces on the edges. Tolerance, ±0.005 in. for widths up to and including 2 in., and ±0.010 in. for widths exceeding 2 in. The required length of the finished edge (to allow free shackle movement or sliding movement) must be indicated.

Thickness—Aggregate of the nominal thicknesses of all leaves at the center of the spring. The actual thickness may differ from this figure because of the rolling tolerances in the bars.

Leaf Ends—The leaf ends used most generally are:

Square as sheared.
Trimmed to a shape.
Taper rolled.
Taper rolled; trimmed or forged to a shape or both.

Finish—Finish refers to the surface condition of the leaves after heat-treatment. Surface condition is usually specified as one or more of the following:

Leaves left in the same condition as they come from the heat-treating process.
The sheared and trimmed edges of the leaves chamfered on their bearing sides.
Leaves shot peened on the tension surface, (See Section 28 of the SAE "Manual on Design and Application of Leaf Springs.")

Leaf Numbers—(See Fig. 1.) Leaves are designated by numbers, starting with the main leaf which is No. 1. The adjoining leaf is No. 2, and so on. If auxiliary or rebound leaves are used, the auxiliary adjoining the main leaf is Auxiliary Leaf No. 1, the next one Auxiliary No. 2, and so on. (Auxiliary leaves are on that side of the main leaf from which load is applied to the spring ends; away from the side from which load is applied to the spring center.) Helper springs are considered as separate units.

Opening and Overall Height—(See Fig. 1.) Distance from the datum line to the point where the center bolt or cup center intersects the surface of the spring that is in contact with the spring seat.

If the surface in contact with the seat is on the main leaf or an auxiliary leaf (which is characteristic of underslung springs), this distance is called opening.

If the surface in contact with the seat is on the shortest leaf (which is characteristic of overslung springs), this distance is called overall height.

Opening and overall height may be positive or negative (Fig. 1). They are fixed reference dimensions. Tolerance is expressed in terms of load (see Load and Rate).

Clearance—Spring travel possible on the vehicle from the specified load position to the metal-to-metal contact position, disregarding rubber bumpers.

Load and Rate

Installation Effects—Load and rate are the terms usually em-

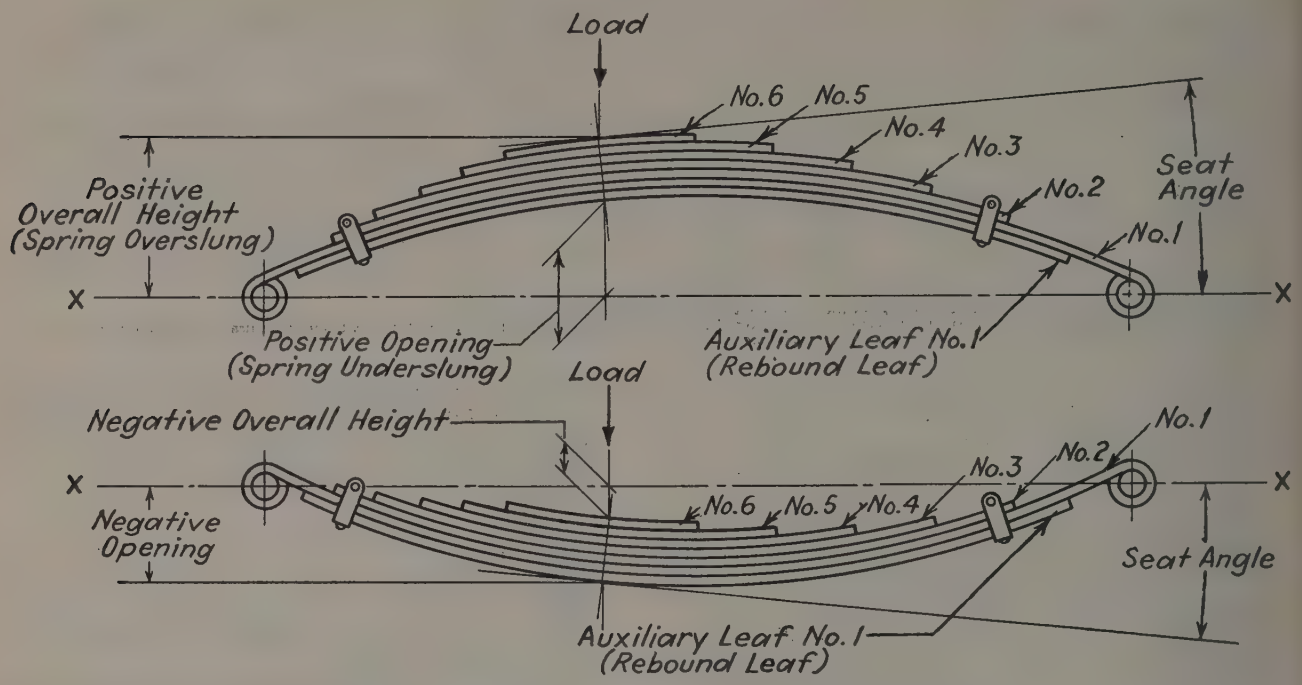


FIG. 1—MEASUREMENT OF OPENING, OVERALL HEIGHT, AND SEAT ANGLE

ployed to describe the capacity of a leaf spring. As used here, they refer to measurements made on the unclamped spring mounted on carriages with rollers.

When the spring is installed in the vehicle, the load and rate will be affected by the clamping of the spring and also by the type of end mounting used. (See Section 21 of SAE "Manual on Design and Application of Leaf Springs.")

Checking Method—To check for load and rate, the spring shall be supported on its ends and the measured load shall be applied downward at the seat. The weight of the spring itself then produces a deflection, but it is not included in the measured load.

The load shall be transmitted from the testing machine head to the shortest spring leaf through a standard SAE loading block, shown in Fig. 2. The loading block shall be centered over the center bolt with the legs of the V resting on the spring.

Before the spring is checked for load or rate, it shall be deflected at least to the metal-to-metal position defined under Clearance in order to remove any temporary recovery. The spring shall then be released to the free position before the load is applied for load and rate checking.

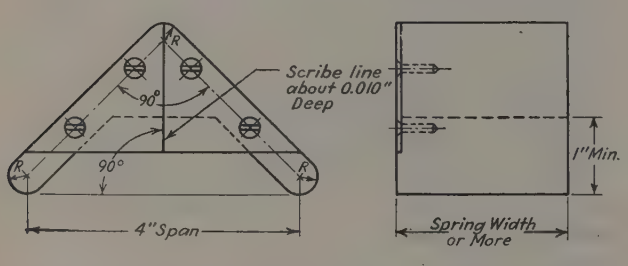


FIG. 2—SPRING LOADING BLOCK

Load and rate shall be measured in terms of the forces exerted by the spring during compression of the spring (compression loads) and not during release of the spring (release loads). The compression load in any position shall be read only after the spring has been thoroughly rapped in that position with a soft metal hammer.

Load—(Rapped compression load) the force in pounds measured on the testing machine, required to deflect the spring to the specified opening or overall height. Tolerance, $\pm 1/8$ to $\pm 1/4$ of the nominal rate, depending upon load, length, and rate.

Rate—half the difference between the loads (rapped compression loads) measured 1 in. above and 1 in. below the specified load position. Tolerance, $\pm 5\%$ on light springs, and $\pm 7\%$ on heavy springs (above 1000 lb per in. rate.)

Specification Requirements—Minimum specification requirements are given in Figs. 3, 4, and 5.

Spring Eyes, Bushings, and Bearings—For some types of spring eyes, spring ends, bushings, and shackle constructions, see Figs. 12, 13, and 14 of SAE "Manual on Design and Application of Leaf Springs."

Diameter tolerances as measured with round plug gages are to be:

Bushed eyes	0.005 in. total.
Unbushed eyes	0.010 in. total.

Eyes of main leaves shall be parallel to each other, parallel to

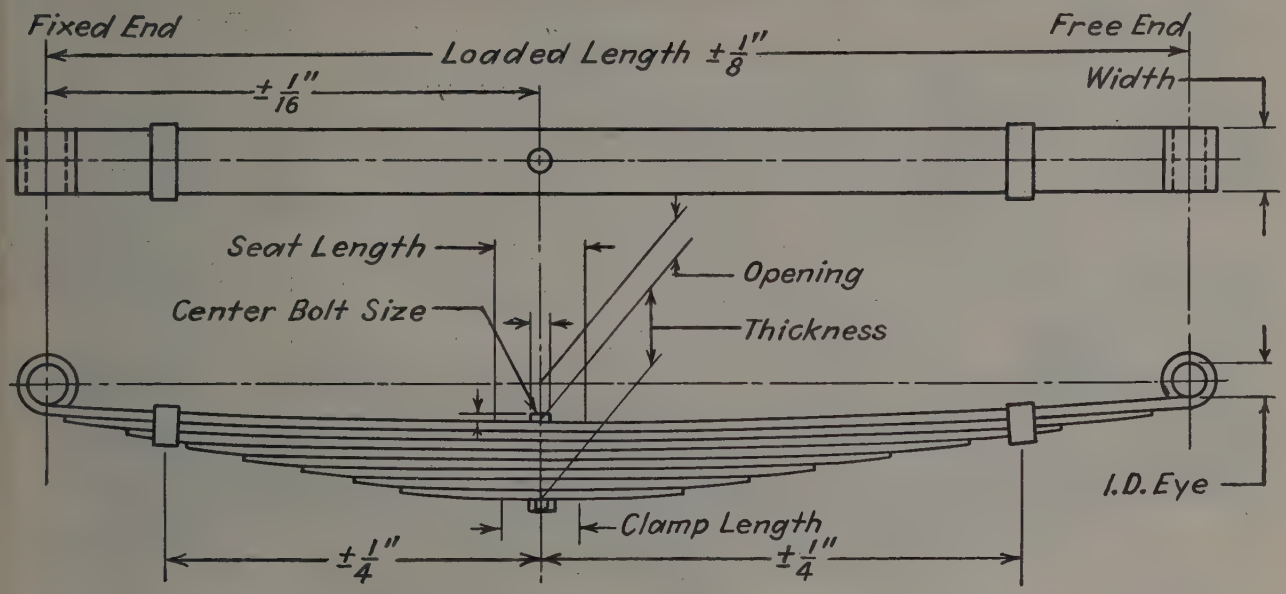


FIG. 3—MINIMUM SPECIFICATION REQUIREMENTS FOR UNDERSLUNG PASSENGER CAR SPRINGS

Spring shown under .... lb load
Clearance, ... in.
Rate, ... lb per in.
Material:.....
Hardness range, ...
Leaves No. .... shot peened

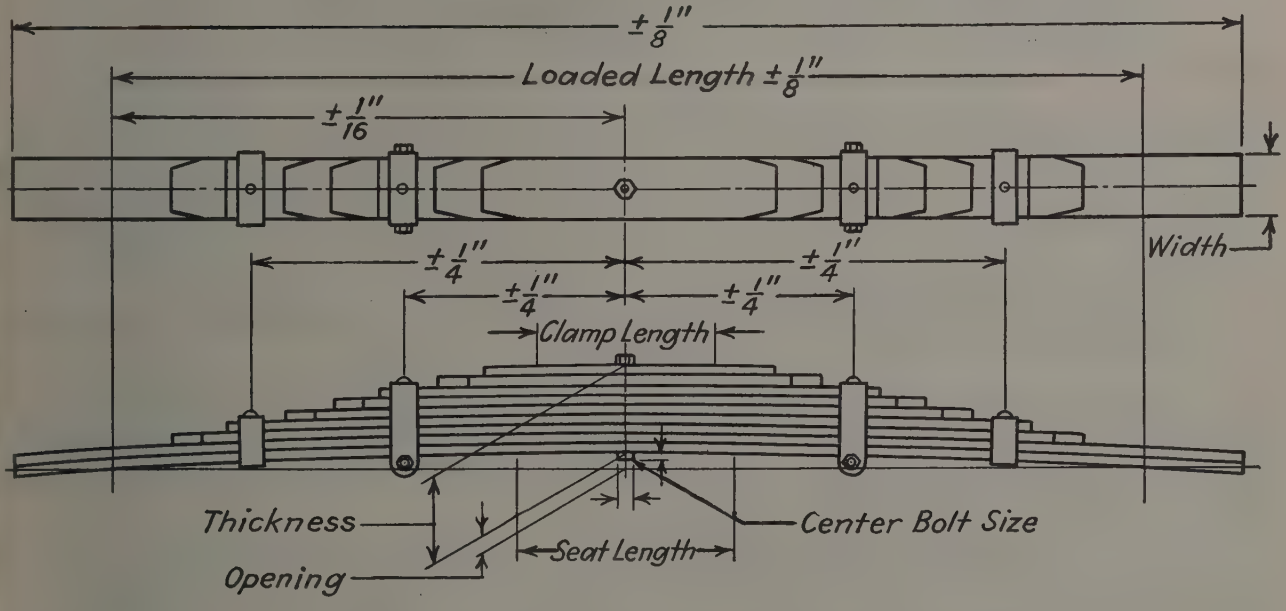


FIG. 4—MINIMUM SPECIFICATION REQUIREMENTS FOR SPRINGS WITH PLAIN ENDS

Spring shown under .... lb load
Clearance, ... in.
Rate, ... lb per in.
Material: .....
Hardness range, ...
Leaves No. .... shot peened

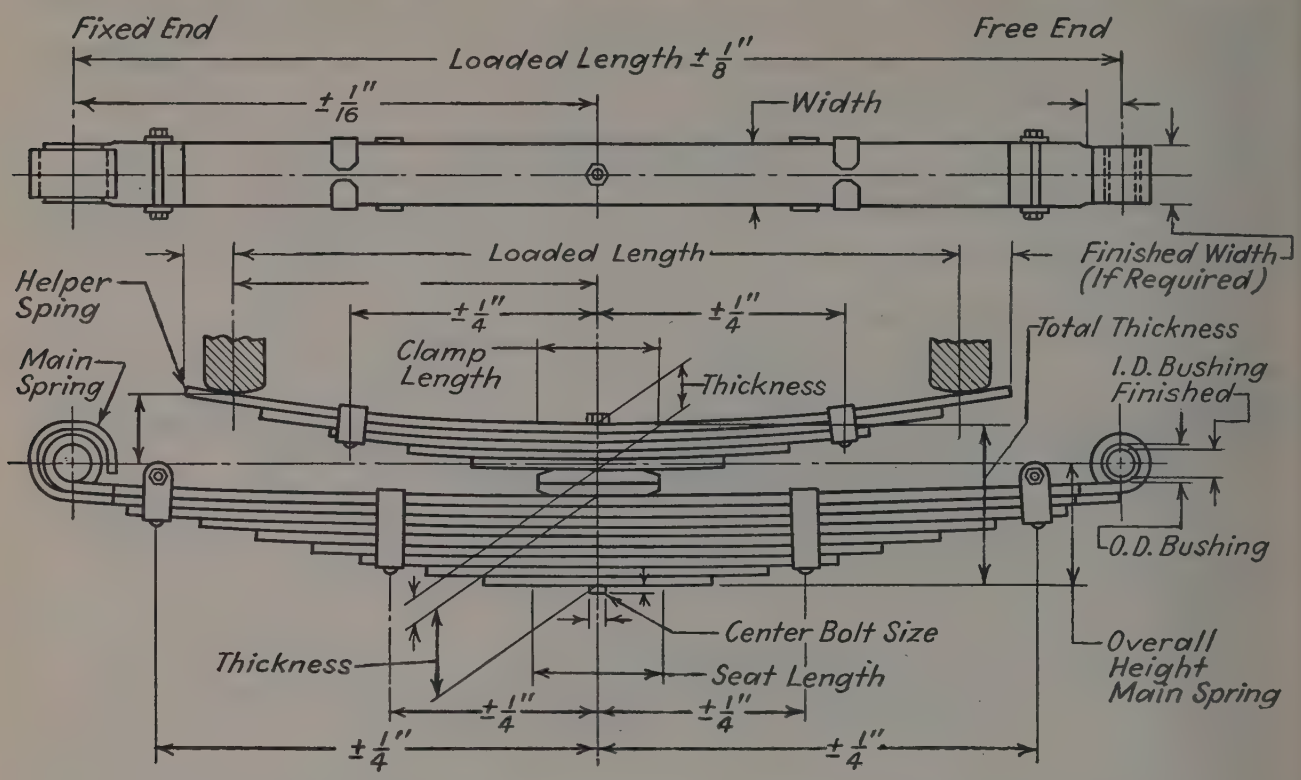


FIG. 5—MINIMUM SPECIFICATION REQUIREMENTS FOR OVERSLUNG COMMERCIAL VEHICLE SPRINGS

Springs shown under .... lb load
Helper to contact at .... lb load on main spring
Clearance, ... in.
Rate of main spring, ... lb per in.
Rate of helper spring, ... lb per in.
Material: .....
Hardness range, ...
Leaves No. .... shot peened

the surface of the spring seat, and square to the centerline of the main leaf within the following limits:

Passenger car springs.....	±3/32 in. in 18 in.
Commercial vehicle springs.....	±3/16 in. in 18 in.

Alignment and Rebound Clips—Most automotive leaf springs are fitted with clips of some form which serve primarily to prevent sidewise spreading of the leaves (alignment clips). Only rarely is it their purpose to assist the main leaf on rebound (rebound clips).

When clips are used on passenger car springs equipped with spring covers, the clips must be of compact design to fit the clip pockets provided in such covers.

Clips employed for passenger car springs show a great deal of variety in design, but commercial vehicle springs are generally equipped with either bolt-type or clinch-type clips. (See Fig. 24 of SAE "Manual on Design and Application of Leaf Springs.") Dimensions must be chosen to suit the individual service requirement.

Spring Center Bolts—The center bolt is required to hold the spring leaves together before installation and to act as a locating dowel during installation. The center bolt should not be depended upon to prevent the shifting of leaves due to driving and braking forces.

Therefore, the physical properties of carbon-steel bolts are usually high enough to permit their use in passenger car springs. However, when center bolts are highly stressed in the handling of the springs and in service, particularly in the case of commercial vehicle springs, it may be necessary to use heat-treated bolts of high physical properties. Table 2 gives center bolt sizes for various spring widths.

In special instances it will be permissible to deviate from the standard center bolt sizes.

When passenger car springs are more than 2½ in. wide, the bolt sizes listed in the first two columns of Table 2 will still be ample, particularly if the springs consist of only a few leaves.

In the case of commercial vehicle springs with leaves thicker

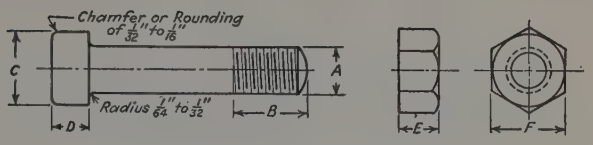
TABLE 2—*Center Bolt Applications*

	PASSENGER CARS		COMMERCIAL VEHICLES			
Spring widths, in..	1½, 1¾, 2	2¼, 2½	1¾	2, 2¼	2½, 3	3½ and over
Minimum center bolt size.....	5/16–24	3/8–24	5/16–24	3/8–24	7/16–20	½–20

TABLE 3—*Center Bolt and Nut Dimensions*[a]

A BOLT SIZE	*B* MINIMUM THREAD LENGTH, IN.	*C* HEAD DIAMETER, IN.	*D* HEAD HEIGHT, IN.	*E* NUT THICKNESS, IN.	*F* WIDTH ACROSS FLATS, IN.
5/16–24	1	1/2	1/4	17/64	1/2
3/8–24	1	9/16	5/16	21/64	9/16
7/16–20	1 1/4	5/8	3/8	3/8	5/8
1/2–20	1 1/4	3/4	7/16	7/16	3/4

[a] Detail specifications for the threads on center bolts and in the nuts are given in the SAE Standard for Screw Threads, Table 10 for bolt threads and Table 11 for threads in the nuts. All threads are American Standard Fine (NF) Series, Class 2 Fit.

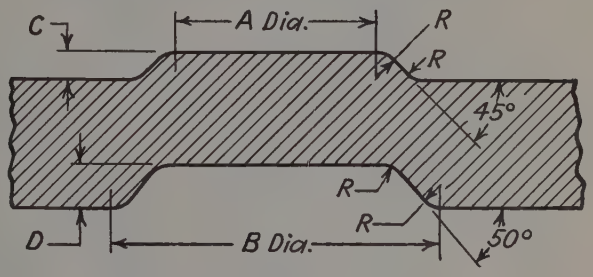


than 0.499 in. and wider than 3½ in., it will be advisable to use bolts larger than those recommended in Table 2.

Cup Center—Cup centers are provided for heavy-duty springs which may not safely depend alone on tight center clamps to prevent a shifting of the spring along the axle due to high driving and braking forces. Sometimes all the leaves are cupped, but the reversed cup center in the main leaf only has proved very effective. (See Fig. 21 of SAE "Manual on Design and Application of Leaf Springs.") It anchors the main leaf securely to the spring seat if the spring is underslung, and to the clamping pad if the spring is mounted above the axle, and thence through the clamping bolts to the spring seat.

TABLE 4—*Center Cup Dimensions*

DIMENSIONS, IN.	*A*	*B*	*C*	*D*	*R*
Tolerance	+0 −1/64	+1/64 −0	+1/64 −0	+0 −1/64	+1/64 −0
To be used with center bolts of 5/16 to 1/2 diam.	2 7/32	1 5/16	1/8	3/16	3/32
To be used with center bolts of 9/16 to 3/4 diam.	1 1/4	1 7/8	3/16	1/4	1/8



Automotive Tube Fittings

SAE Standard

Report of Carburetor Fittings Division approved June 1912 and last revised by Tube, Pipe, Hose, and Lubrication Fittings Technical Committee April 1951.

Flared Type

Details of contour are optional with the manufacturer.[1]

Wrench flats are optional. The dimensions of the first figure in each group apply to all other figures in that group except as shown otherwise.

See General Specifications following Table 12.

[1] Minimum straight thread length where body is undercut or relieved shall not be shorter than K full thread. Minimum pipe-thread length where body is undercut or relieved shall not be shorter than L_2 plus one turn (thread) full thread.

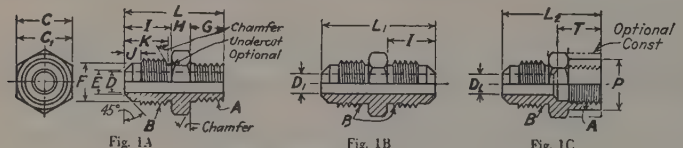


Fig. 1A Fig. 1B Fig. 1C

Fig. 1—Connectors and Unions

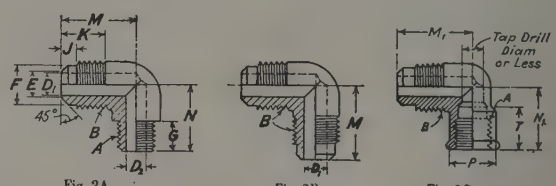


Fig. 2A Fig. 2B Fig. 2C

Fig. 2—Elbows

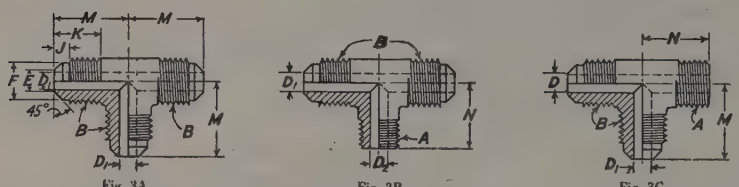


Fig. 3A Fig. 3B Fig. 3C

Fig. 3—Tees

TABLE 1—*Dimensions of Connectors, Unions, Elbows, and Tees (Figs. 1A–3C)*

TUBE OD ±0.002	DRYSEAL TAPER THREAD,[a] A	STRAIGHT THREAD, B	PITCH DIAM (THREAD, B) Min	PITCH DIAM (THREAD, B) Max	C	C_1, INT CONNECTOR	D	D_1	D_2, MAX	E	F
1/8	1/8	5/16-24	0.2806	0.2843	7/16	9/16	5/64	5/64	7/32	7/64	15/64
3/16	1/8	3/8-24	0.3430	0.3468	7/16	9/16	1/8	1/8	7/32	5/32	19/64
1/4	1/8	7/16-20	0.3995	0.4037	7/16	9/16	3/16	3/16	7/32	7/32	11/32
5/16	1/8	1/2-20	0.4619	0.4662	1/2	9/16	7/32	7/32	7/32	1/4	13/32
5/16	1/4	1/2-20	0.4619	0.4662	9/16	—	7/32	—	11/32	1/4	13/32
3/8	1/4	5/8-18	0.5828	0.5875	5/8	11/16	9/32	9/32	11/32	5/16	17/32
7/16	1/4	11/16-16	0.6407	0.6455	11/16	11/16	5/16	5/16	11/32	11/32	37/64
1/2	3/8	3/4-16	0.7029	0.7079	3/4	13/16	13/32	13/32	13/32	7/16	41/64
5/8	1/2	7/8-14	0.8216	0.8270	7/8	1	1/2	1/2	9/16	17/32	3/4
3/4	1/2	1 1/16-14	1.0092	1.0145	1 1/16	1 1/16	9/16	5/8	9/16	23/32	15/16
7/8	3/4	1 1/4-12	1.1879	1.1941	1 1/4	1 1/4	3/4	3/4	3/4	51/64	1 1/8
1	1	1 3/8-12	1.3127	1.3190	1 3/8	1 1/2	7/8	7/8	15/16	15/16	1 1/4

TUBE OD, ±0.002	G[b]	H	I	J	K, MIN FULL THREAD	L[b] ±1/32	L_1 ±1/32	L_2[b, c]	M ±1/32	M_1 ±1/32	N[b] ±1/32	N_1[b, c] ±1/32	P	T[b, c]
1/8	3/8	5/32	5/16	1/8	15/64	27/32	25/32	27/32	5/8	11/16	11/16	11/16	9/16	3/8
3/16	3/8	3/16	3/8	1/8	19/64	15/16	15/16	15/16	3/4	3/4	3/4	3/4	9/16	3/8
1/4	3/8	3/16	1/2	5/32	13/32	1 1/16	1 3/16	1 1/16	7/8	7/8	3/4	3/4	9/16	3/8
5/16	3/8	7/32	9/16	3/16	15/32	1 5/32	1 11/32	1 5/32	15/16	15/16	3/4	3/4	9/16	3/8
5/16	9/16	7/32	9/16	3/16	15/32	1 11/32	—	—	15/16	—	15/16	—	—	—
3/8	9/16	1/4	5/8	7/32	33/64	1 7/16	1 1/2	1 5/16	1	1 1/16	1 1/16	7/8	1 1/16	9/16
7/16	9/16	9/32	11/16	1/4	9/16	1 17/32	1 21/32	1 13/32	1 1/8	1 1/8	1 1/16	15/16	1 1/16	9/16
1/2	9/16	5/16	3/4	1/4	5/8	1 5/8	1 13/16	1 9/16	1 3/16	1 9/32	1 1/8	1	1 3/16	9/16
5/8	3/4	3/8	7/8	9/32	47/64	2	2 1/8	1 13/16	1 7/16	1 1/2	1 3/8	1 1/4	1	3/4
3/4	3/4	7/16	1	9/32	55/64	2 3/16	2 7/16	2	1 5/8	1 5/8	1 1/2	1 5/16	1 1/16	3/4
7/8	3/4	1/2	1 1/8	3/8	61/64	2 3/8	2 3/4	2 1/4	1 3/4	1 7/8	1 11/16	1 7/16	1 1/4	3/4
1	15/16	9/16	1 1/8	3/8	1 1/32	2 5/8	2 13/16	2 7/16	1 15/16	2 1/16	1 15/16	1 9/16	1 1/2	15/16

[a] Dryseal American (National) Standard Taper Pipe Thread unless purchaser specifically authorizes use of SAE Short Dryseal Taper Pipe Thread. See SAE Standard for Dryseal Pipe Threads, General Specifications, and Tables 1 and 2.

[b] With SAE Short Pipe Thread, dimensions G, L, L_2, N, N_1 and T may be reduced in accordance with reduction of pipe-thread length. See SAE Standard for Dryseal Pipe Threads, Tables 3 and 4.

[c] Tap-drill depths given require use of bottoming taps to produce standard full thread length. For increased tap clearance, see Internal Taper Pipe Threads in the General Specifications following Table 12.

Flared Type

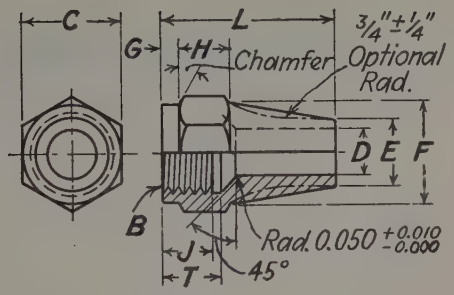


FIG. 4—SAE STANDARD FLARED-TYPE NUTS

TABLE 2—*Dimensions of Nuts for Connectors, Unions, Elbows, and Tees (Fig. 4)*

TUBE OD ±0.002	STRAIGHT THREAD, B	PITCH DIAMETER (THREAD B)		C	D		E	F	G	H	J, FULL THREAD	L		T
		Min	Max		Min	Max						Long	Short	
1/8	5/16–24	0.2854	0.2902	3/8	0.130	0.135	1/4	3/8	3/32	1/8	5/32	3/4	1/2	7/32
3/16	3/8–24	0.3479	0.3528	7/16	0.192	0.197	5/16	7/16	3/32	3/16	7/32	13/16	5/8	9/32
1/4	7/16–20	0.4050	0.4104	9/16	0.255	0.260	3/8	9/16	1/8	1/4	9/32	15/16	3/4	11/32
5/16	1/2–20	0.4675	0.4731	5/8	0.317	0.322	7/16	5/8	1/8	5/16	5/16	1 1/8	7/8	3/8
3/8	5/8–18	0.5889	0.5949	3/4	0.380	0.385	1/2	3/4	1/8	3/8	3/8	1 5/16	1	7/16
7/16	11/16–16	0.6469	0.6531	13/16	0.442	0.447	9/16	13/16	1/8	7/16	13/32	1 1/2	1 1/16	15/32
1/2	3/4–16	0.7094	0.7159	7/8	0.505	0.510	5/8	7/8	1/8	1/2	15/32	1 5/8	1 1/8	17/32
5/8	7/8–14	0.8286	0.8356	1 1/16	0.630	0.635	3/4	1 1/16	1/8	5/8	19/32	1 7/8	1 5/16	21/32
3/4	1 1/16–14	1.0161	1.0230	1 1/4	0.755	0.760	7/8	1 1/4	1/8	3/4	11/16	2 3/16	1 1/2	25/32
7/8	1 1/4 –12	1.1959	1.2039	1 1/2	0.880	0.885	1 1/16	1 1/2	1/8	7/8	11/16	2 5/16	1 5/8	25/32
1	1 3/8 –12	1.3209	1.3291	1 5/8	1.005	1.010	1 3/16	1 5/8	1/8	7/8	11/16	2 1/2	1 13/16	13/16

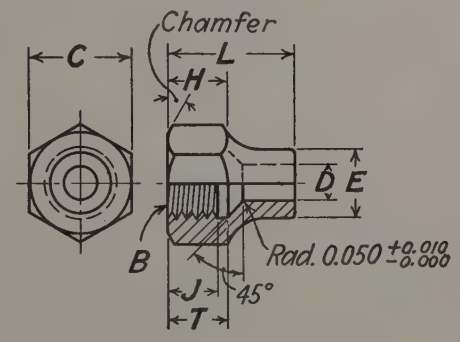


FIG. 5—REFRIGERATION AND MARINE FLARED-TYPE NUTS

TABLE 3—*Dimensions of Nuts for Connectors, Unions, Elbows, and Tees (Fig. 5)*

TUBE OD ± 0.002	STRAIGHT THREAD, B	PITCH DIAMETER (THREAD B)		C	D		E	H	J, FULL THREAD	L	T
		Min	Max		Min	Max					
3/16	3/8–24	0.3479	0.3528	5/8	0.192	0.197	13/32	3/8	7/32	7/8	9/32
1/4	7/16–20	0.4050	0.4104	3/4	0.255	0.260	15/32	7/16	9/32	15/16	11/32
5/16	1/2–20	0.4675	0.4731	3/4	0.317	0.322	15/32	7/16	5/16	15/16	3/8
3/8	5/8–18	0.5889	0.5949	7/8	0.380	0.385	19/32	1/2	3/8	1 1/16	7/16
7/16	11/16–16	0.6469	0.6531	1	0.442	0.447	3/4	9/16	13/32	1 3/16	15/32
1/2	3/4–16	0.7094	0.7159	1	0.505	0.510	3/4	9/16	15/32	1 3/16	17/32
5/8	7/8–14	0.8286	0.8356	1 1/8	0.630	0.635	15/16	3/4	19/32	1 7/16	21/32
3/4	1 1/16–14	1.0161	1.0230	1 3/8	0.755	0.760	1 1/8	1	23/32	1 3/4	25/32

Details of contour are optional with the manufacturer.[2] Wrench flats are optional. The dimensions of the first figure in each group apply to all other figures in that group except as shown otherwise.

See General Specifications following Table 12.

[2] Minimum straight thread length where body is undercut or relieved shall not be shorter than K full thread. Minimum pipe-thread length where body is undercut or relieved shall not be shorter than L_2 plus one turn (thread) full thread.

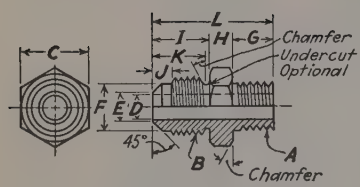


Fig. 6A

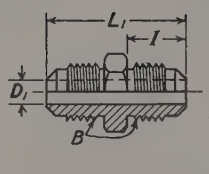


Fig. 6B

Fig. 6—Connectors and Unions

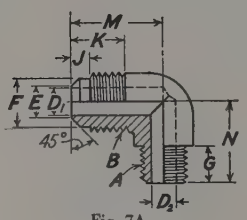


Fig. 7A

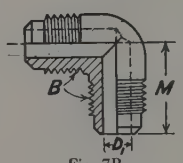


Fig. 7B

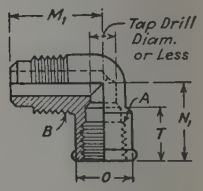


Fig. 7C

Fig. 7—Elbows

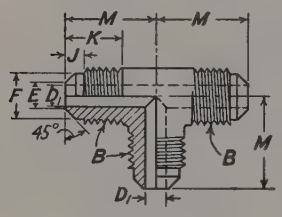


Fig. 8A

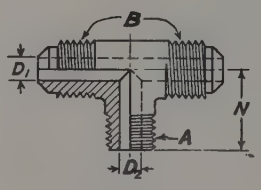


Fig. 8B

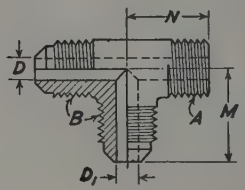


Fig. 8C

Fig. 8—Tees

TABLE 4—*Dimensions of Connectors, Unions, Elbows, and Tees (Figs. 6A-8C)*

TUBE OD ±0.002	DRYSEAL TAPER THREAD,[a] A	STRAIGHT THREAD, B	PITCH DIAMETER (THREAD B) Min	PITCH DIAMETER (THREAD B) Max	C	D	D_1	D_2, MAX	E	F	G[b]	H	I	J	K, MIN FULL THD	L[b] ±1/32	L_1 ±1/32	M ±1/32	M_1 ±1/32	N[b] ±1/32	N_1[b,c] ±1/32	O, MIN	T[b,c]
3/16	1/8	3/8–24	0.3430	0.3468	7/16	1/8	1/8	7/32	5/32	19/64	3/8	3/16	3/8	1/8	19/64	15/16	15/16	3/4	3/4	3/4	3/4	9/16	3/8
1/4	1/8	7/16–20	0.3995	0.4037	9/16	3/16	3/16	7/32	7/32	11/32	3/8	3/16	1/2	5/32	13/32	1 1/16	1 3/16	7/8	7/8	7/8	3/4	9/16	3/8
5/16	1/8	1/2–20	0.4619	0.4662	5/8	7/32	7/32	7/32	1/4	13/32	3/8	7/32	9/16	3/16	15/32	1 5/32	1 11/32	15/16	15/16	7/8	3/4	9/16	3/8
3/8	1/4	5/8–18	0.5828	0.5875	3/4	9/32	9/32	11/32	5/16	17/32	9/16	1/4	5/8	7/32	33/64	1 7/16	1 1/2	1	1 1/16	1 1/8	7/8	1 1/16	9/16
7/16	1/4	11/16–16	0.6407	0.6455	13/16	5/16	5/16	11/32	11/32	37/64	9/16	9/32	1 1/16	1/4	9/16	1 17/32	1 21/32	1 1/8	1 1/8	1 3/16	15/16	1 1/16	9/16
1/2	3/8	3/4–16	0.7029	0.7079	7/8	13/32	13/32	13/32	7/16	41/64	9/16	5/16	3/4	1/4	5/8	1 5/8	1 13/16	1 3/16	1 9/32	1 3/16	1	1 3/16	9/16
5/8	1/2	7/8–14	0.8216	0.8270	1	1/2	1/2	9/16	17/32	3/4	3/4	3/8	7/8	9/32	47/64	2	2 1/8	1 7/16	1 1/2	1 7/16	1 1/4	1	3/4
3/4	1/2	1 1/16–14	1.0092	1.0145	1 3/16	9/16	5/8	9/16	23/32	15/16	3/4	7/16	1	9/32	55/64	2 3/16	2 7/16	1 5/8	1 5/8	1 9/16	1 5/16	1	3/4

[a] Dryseal American (National) Standard Taper Pipe Thread unless purchaser specifically authorizes use of SAE Short Dryseal Taper Pipe Thread. See SAE Standard for Dryseal Pipe Threads, General Specifications, and Tables 1 and 2.

[b] With SAE Short Pipe Thread, dimensions G, L, N, N_1 and T may be reduced in accordance with reduction of pipe-thread length. See SAE Standard for Dryseal Pipe Threads, Tables 3 and 4.

[c] Tap-drill depths given require use of bottoming taps to produce standard full thread length. For increased tap clearance, see Internal Taper Pipe Threads in the General Specifications following Table 12.

Ball-Sleeve (Compression) Type

Details of contour are optional with the manufacturer.[3]

[3] Minimum straight thread length where body is undercut or relieved shall not be shorter than J full thread. Minimum pipe-thread length where body is undercut or relieved shall not be shorter than L_2 plus one turn (thread) full thread.

Wrench flats are optional. The dimensions of the first figure in each group apply to all other figures in that group except as shown otherwise.

See General Specifications following Table 12.

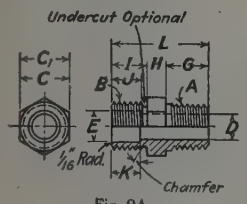


Fig. 9A

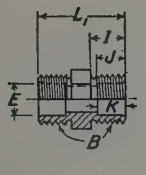


Fig. 9B

Fig. 9—Connectors and Unions

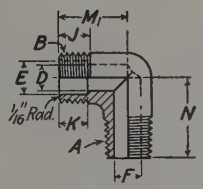


Fig. 10A

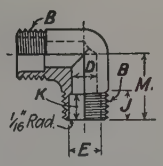


Fig. 10B

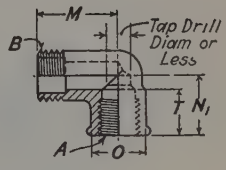


Fig. 10C

Fig. 10—Elbows

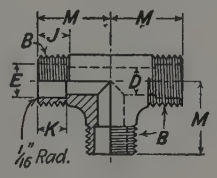


Fig. 11A

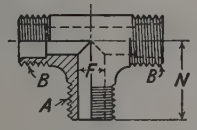


Fig. 11B

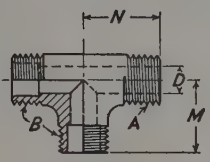


Fig. 11C

Fig. 11—Tees

TABLE 5—*Dimensions of Connectors, Unions, Elbows, and Tees (Figs. 9A–11C)*

TUBE OD ±0.002	DRYSEAL TAPER THREAD,[a] A	STRAIGHT THREAD, B	PITCH DIAMETER (THREAD B) Min	PITCH DIAMETER (THREAD B) Max	C	C_1, UNIONS	D	E ±0.002	F, MAX	G^b	H	I	J, FULL THD	K	L^b	L_1 ±1/32	M ±1/32	M_1 ±1/32	N^b ±1/32	N_1[b,c] ±1/32	O, MIN	$T^{b,c}$
1/8	1/8	5/16–24	0.2806	0.2843	7/16	5/16	3/32	0.134	7/32	3/8	5/32	1/4	3/16	3/16	25/32	21/32	11/16	5/8	11/16	9/16	9/16	3/8
3/16	1/8	3/8–24	0.3430	0.3468	7/16	3/8	1/8	0.195	7/32	3/8	3/16	9/32	7/32	7/32	27/32	3/4	11/16	5/8	11/16	9/16	9/16	3/8
1/4	1/8	7/16–24	0.4055	0.4093	7/16	7/16	3/16	0.260	7/32	3/8	3/16	5/16	1/4	1/4	7/8	13/16	11/16	5/8	3/4	9/16	9/16	3/8
5/16	1/8	1/2–24	0.4678	0.4717	1/2	1/2	1/4	0.323	15/64	3/8	3/16	11/32	9/32	9/32	29/32	7/8	11/16	5/8	3/4	9/16	9/16	3/8
5/16	1/4	1/2–24	0.4678	0.4717	9/16	—	1/4	0.323	5/16	9/16	—	11/32	9/32	9/32	13/32	—	—	11/16	27/32	—	—	—
3/8	1/4	9/16–24	0.5303	0.5342	9/16	9/16	5/16	0.387	11/32	9/16	7/32	3/8	5/16	5/16	15/32	31/32	13/16	3/4	15/16	3/4	11/16	9/16
7/16	1/4	5/8–24	0.5927	0.5967	5/8	5/8	5/16	0.451	11/32	9/16	7/32	13/32	11/32	11/32	13/16	1 1/32	29/32	27/32	1	3/4	11/16	9/16
1/2	3/8	11/16–20	0.6494	0.6537	11/16	11/16	13/32	0.516	13/32	9/16	7/32	7/16	3/8	3/8	17/32	1 3/32	1	15/16	1 1/8	7/8	13/16	9/16
5/8	1/2	13/16–18	0.7704	0.7750	7/8	13/16	1/2	0.644	9/16	3/4	1/4	1/2	7/16	3/8	1 1/2	1 1/4	1 1/16	1 1/16	1 5/16	1	1	3/4
3/4	1/2	1–18	0.9578	0.9625	1	1	9/16	0.772	9/16	3/4	5/16	9/16	1/2	7/16	1 5/8	1 7/16	1 3/16	1 3/16	1 1/2	1	1	3/4

[a] Dryseal American (National) Standard Taper Pipe Thread unless purchaser specifically authorizes use of SAE Short Dryseal Taper Pipe Thread. See SAE Standard for Dryseal Pipe Threads, General Specifications, and Tables 1 and 2.

[b] With SAE Short Pipe Thread, dimensions G, L, N, N_1, and T may be reduced in accordance with reduction of pipe-thread length. See SAE Standard for Dryseal Pipe Threads, Tables 3 and 4.

[c] Tap-drill depths given require use of bottoming taps to produce standard full thread length. For increased tap clearance, see Internal Taper Pipe Threads in the General Specifications following Table 12.

Ball-Sleeve (Compression) Type

FIG. 12—BALL SLEEVES

FIG. 13—NUTS

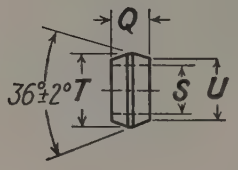


FIG. 12

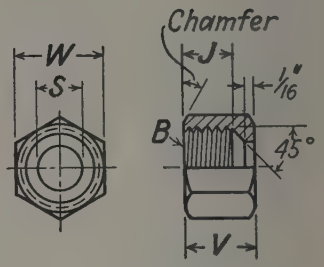


FIG. 13

TABLE 6—*Dimensions of Ball Sleeves and Nuts (Figs. 12 and 13)*

TUBE OD ±0.002	STRAIGHT THREAD, *B*	PITCH DIAM		*J*, FULL THREAD	*Q*	*S* ±0.002	*T*	*U*	*V*	*W*
		Min	Max							
1/8	5/16–24	0.2854	0.2902	3/16	3/16	0.130	3/16	0.138	3/8	3/8
3/16	3/8–24	0.3479	0.3528	7/32	7/32	0.193	17/64	0.201	13/32	7/16
1/4	7/16–24	0.4104	0.4153	1/4	1/4	0.257	11/32	0.266	7/16	1/2
5/16	1/2–24	0.4729	0.4780	1/4	1/4	0.320	13/32	0.329	7/16	9/16
3/8	9/16–24	0.5354	0.5405	9/32	1/4	0.383	15/32	0.393	15/32	5/8
7/16	5/8–24	0.5979	0.6031	5/16	5/16	0.447	17/32	0.457	1/2	11/16
1/2	11/16–20	0.6550	0.6606	13/32	3/8	0.511	19/32	0.522	5/8	13/16
5/8	13/16–18	0.7764	0.7824	13/32	3/8	0.638	23/32	0.650	5/8	15/16
3/4	1–18	0.9639	0.9701	7/16	7/16	0.765	7/8	0.778	11/16	13/16

Inverted Flared Type

FIG. 14—NUTS

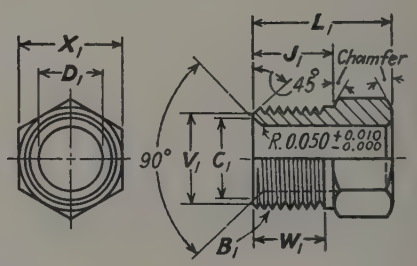


TABLE 7—*Dimensions of Nuts (Fig. 14)*

TUBE OD ±0.002	STRAIGHT THREAD, B_1	PITCH DIAM (THREAD B_1)		C_1		D_1		J_1	L_1	V_1		W_1, FULL THREAD	X_1
		Min	Max	Min	Max	Min	Max			Min	Max		
1/8	5/16–28	0.2849	0.2883	0.221	0.225	0.130	0.133	9/32	1/2	0.246	0.261	1/4	5/16
3/16	3/8–24	0.3430	0.3468	0.268	0.272	0.192	0.195	5/16	17/32	0.301	0.316	9/32	3/8
1/4	7/16–24	0.4055	0.4093	0.331	0.335	0.255	0.258	3/8	19/32	0.363	0.378	5/16	7/16
5/16	1/2–20	0.4619	0.4662	0.393	0.397	0.317	0.320	13/32	21/32	0.415	0.430	11/32	1/2
3/8	5/8–18	0.5828	0.5875	0.487	0.491	0.380	0.383	13/32	25/32	0.533	0.548	3/8	5/8
7/16	11/16–18	0.6455	0.6500	0.550	0.554	0.442	0.445	1/2	7/8	0.595	0.610	13/32	11/16
1/2	3/4–18	0.7079	0.7125	0.612	0.616	0.505	0.508	17/32	29/32	0.658	0.673	7/16	3/4
5/8	7/8–18	0.8329	0.8375	0.737	0.741	0.630	0.633	17/32	31/32	0.783	0.798	15/32	7/8
3/4	1 1/16–16	1.0154	1.0204	0.906	0.912	0.755	0.761	19/32	1 1/16	0.961	0.976	15/32	1 1/16

Inverted Flared Type—Standard Series

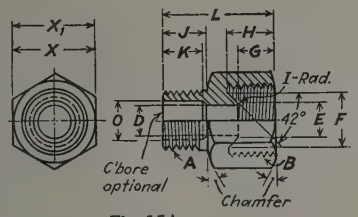


Fig. 15A

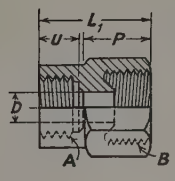


Fig. 15B

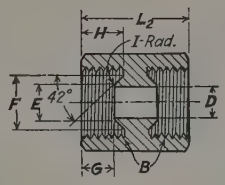


Fig. 15C

Fig. 15—Connectors and Unions

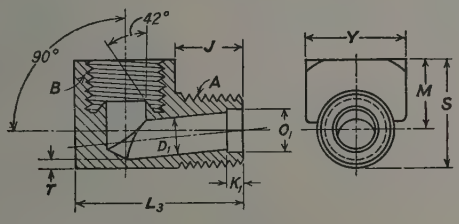


Fig. 16—Elbows

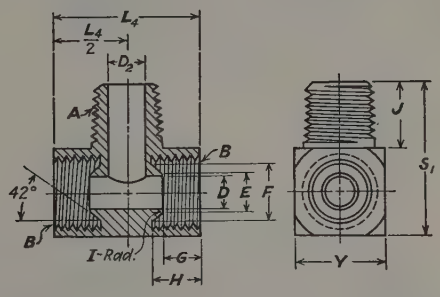


Fig. 17—Tees

Details of contour are optional with the manufacturer. Wrench flats are optional. The dimensions of the first figure in each group apply to all other figures in that group except as shown otherwise.

See General Specifications following Table 12.

TABLE 8—*Dimensions of Connectors, Unions, Elbows, and Tees (Figs. 15A–17)*

TUBE OD ±0.002	DRYSEAL TAPER THREAD,[a] A	STRAIGHT THREAD, B	PITCH DIAM (THREAD B) Min	PITCH DIAM (THREAD B) Max	D	D_1	D_2, MAX	E Min	E Max	F, FOR REF Min	F, FOR REF Max	G, SMALL SEAT DEPTH	H, SEAT DEPTH	MIN FULL THD (THD B)	I, RAD	J[b]
1/8	1/8	5/16–28	0.2893	0.2937	5/64	5/64	7/32	0.104	0.108	0.216	0.220	3/16	1/4	13/64	0.006	3/8
3/16	1/8	3/8–24	0.3479	0.3528	1/8	0.116	7/32	0.151	0.155	0.263	0.267	13/64	17/64	7/32	0.006	3/8
1/4	1/8	7/16–24	0.4104	0.4153	3/16	0.177	7/32	0.214	0.218	0.326	0.330	13/64	17/64	7/32	0.031	3/8
5/16	1/8	1/2–20	0.4675	0.4731	7/32	13/64	7/32	0.276	0.280	0.388	0.392	15/64	19/64	1/4	0.031	3/8
5/16	1/4	1/2–20	0.4675	0.4731	7/32	7/32	—	0.276	0.280	0.388	0.392	15/64	19/64	1/4	0.031	9/16
3/8	1/4	5/8–18	0.5889	0.5949	9/32	0.272	11/32	0.342	0.346	0.482	0.486	17/64	11/32	9/32	0.031	9/16
7/16	1/4	11/16–18	0.6514	0.6573	11/32	21/64	11/32	0.405	0.409	0.545	0.549	19/64	3/8	5/16	0.031	9/16
1/2	3/8	3/4–18	0.7139	0.7199	13/32	25/64	13/32	0.467	0.471	0.607	0.611	5/16	25/64	21/64	0.031	9/16

TUBE OD ±0.002	K	K_1	L^b +1/32 −0	$L_1{}^{b,c}$ +1/32 −0	L_2 +1/32 −0	$L_3{}^b$	L_4 +1/32 −0	M	O	O_1	P	S	$S_1{}^b$	T	$U^{b,c}$	X, EXT CONNECTOR AND UNION	X_1, INT CONNECTOR	Y
1/8	3/16	1/4	5/8	23/32	9/16	25/32	25/32	13/64	7/32	7/32	11/32	13/32	25/32	1/32	3/8	13/32	1/2	13/32
3/16	15/64	5/32	11/16	3/4	5/8	13/16	13/16	17/64	7/32	1/4	3/8	15/32	13/16	1/32	3/8	7/16	1/2	7/16
1/4	9/32	3/32	47/64	3/4	5/8	7/8	13/16	21/64	7/32	1/4	3/8	17/32	7/8	1/32	3/8	1/2	1/2	1/2
5/16	—	3/32	25/32	25/32	45/64	15/16	15/16	13/32	7/32	1/4	13/32	39/64	15/16	3/64	3/8	9/16	9/16	9/16
5/16	1/2	1/2	31/32	—	—	15/32	—	29/64	5/16	5/16	—	3/4	—	3/16	—	9/16	—	19/32
3/8	13/32	7/64	11/64	1 1/32	51/64	1 1/4	1 1/8	29/64	11/32	11/32	15/32	47/64	1 1/4	1/32	9/16	23/32	23/32	1 1/16
7/16	—	—	1 1/16	1 1/16	7/8	15/16	13/16	17/32	11/32	—	1/2	13/16	15/16	3/64	9/16	25/32	25/32	3/4
1/2	—	5/32	1 1/16	1 3/32	29/32	1 13/32	15/16	17/32	13/32	15/32	17/32	7/8	1 13/32	1/32	9/16	7/8	7/8	27/32

[a] Dryseal American (National) Standard Taper Pipe Thread unless purchaser specifically authorizes use of SAE Short Dryseal Taper Pipe Thread. See SAE Standard for Dryseal Pipe Threads, General Specifications, and Tables 1 and 2.

[b] With SAE Short Pipe Thread, dimensions J, L, S, and U may be reduced in accordance with reduction of pipe-thread length. See SAE Standard for Dryseal Pipe Threads, Table 3 and 4.

[c] Tap-drill depths given require use of bottoming taps to produce standard full thread length. For increased tap clearance, see Internal Taper Pipe Threads in the General Specifications following Table 12.

Inverted Flared Type—Heavy Series

See General Specifications following Table 12.

Details of contour are optional with the manufacturer. Wrench flats are optional. The dimensions of the first figure in each group apply to all other figures in that group except as shown otherwise.

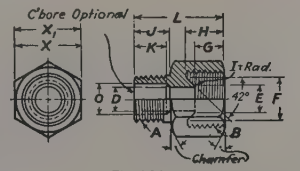


Fig. 18A

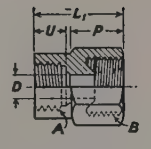


Fig. 18B

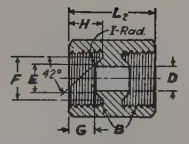


Fig. 18C

Fig. 18—Connectors and Unions

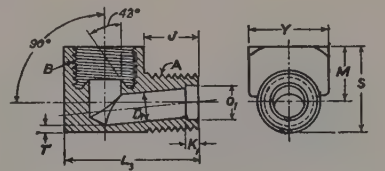


Fig. 19A

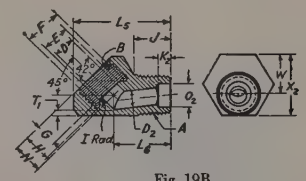


Fig. 19B

Fig. 19—Elbows

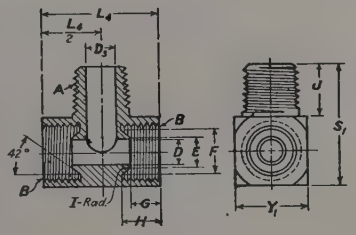


Fig. 20A

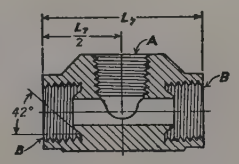
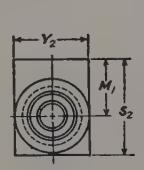


Fig. 20B



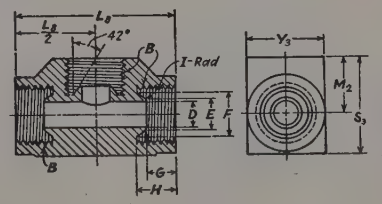


Fig. 20C

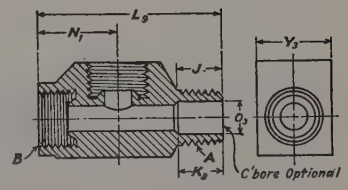


Fig 20D

Fig. 20—Tees

TABLE 9—*Dimensions of Connectors, Unions, Elbows, and Tees (Figs. 18A–20D)*

TUBE OD ±0.002	DRYSEAL TAPER THREAD,[a] A	STRAIGHT THREAD, B	PITCH DIAM (THREAD B) Min	PITCH DIAM (THREAD B) Max	D	D_1	D_2	D_3, MAX	E Min	E Max	F, FOR REF Min	F, FOR REF Max	G, SMALL SEAT DEPTH	H, SEAT DEPTH	MIN FULL THD (THD B)	I, RAD	J^b	K	K_1	K_2	K_3	L^b +1/32 −0	$L_1{}^b$ +1/32 −0	L_2 +1/32 −0	$L_3{}^b$	L_4 +1/32 −0
1/8	1/8	5/16–28	0.2893	0.2937	5/64	—	1/8	7/32	0.104	0.108	0.216	0.220	3/16	1/4	13/64	0.006	3/8	3/16	1/4	3/32	3/8	5/8	23/32	19/32	25/32	25/32
3/16	1/8	3/8–24	0.3479	0.3528	1/8	1/8	5/32	7/32	0.151	0.155	0.263	0.267	13/64	17/64	7/32	0.006	3/8	15/64	3/32	3/32	3/8	11/16	3/4	5/8	27/32	13/16
1/4	1/8	7/16–24	0.4104	0.4153	3/16	0.177	3/16	7/32	0.214	0.218	0.326	0.330	13/64	17/64	7/32	0.031	3/8	9/32	3/32	3/32	—	47/64	3/4	5/8	29/32	27/32
5/16	1/8	1/2–20	0.4675	0.4731	7/32	7/32	13/64	7/32	0.276	0.280	0.388	0.392	15/64	19/64	1/4	0.031	3/8	—	—	—	—	25/32	25/32	45/64	31/32	15/16
3/8	1/4	5/8–18	0.5889	0.5949	9/32	9/32	9/32	11/32	0.342	0.346	0.482	0.486	17/64	11/32	9/32	0.031	9/16	13/32	—	3/32	—	1 1/64	1 1/32	51/64	1 5/16	1 5/32
7/16	1/4	11/16–18	0.6514	0.6573	11/32	21/64	5/16	11/32	0.405	0.409	0.545	0.549	19/64	3/8	5/16	0.031	9/16	—	—	3/32	—	1 13/64	1 1/16	7/8	1 13/32	1 7/32
1/2	3/8	3/4–18	0.7139	0.7199	13/32	3/8	3/8	13/32	0.467	0.471	0.607	0.611	5/16	25/64	21/64	0.031	9/16	—	5/32	3/32	—	1 11/16	1 3/32	29/32	1 15/32	1 3/8
5/8	1/2	7/8–18	0.8389	0.8449	17/32	1/2	1/2	9/16	0.592	0.596	0.732	0.736	21/64	13/32	1 1/32	0.031	3/4	17/32	7/32	3/16	—	1 5/16	1 5/16	31/32	1 13/16	1 9/16
3/4	3/4	1 1/16–16	1.0219	1.0284	5/8	5/8	5/8	3/4	0.703	0.708	0.900	0.905	23/64	15/32	13/32	0.031	3/4	17/32	5/16	1/4	—	1 3/8	1 1/2	1 1/8	2	1 13/16

TUBE OD ±0.002	$L_6{}^b$	$L_6{}^b$	L_7 +1/32 −0	L_8 +1/32 −0	$L_9{}^b$	M	M_1	M_2	N	N_1	O	O_1	O_2	O_3	P	S	$S_1{}^b$	S_2	S_3	T	T_1	$U^{b,c}$	W	X	X_1, INT CONNECTOR AND UNION	X_2	Y	Y_1	Y_2	Y_3
1/8	13/16	33/64	13/32	15/16	15/32	13/64	25/64	21/64	7/32	15/32	7/32	7/32	1/4	3/16	11/32	13/32	25/32	5/8	17/32	1/32	5/64	3/8	19/64	13/32	1/2	1/2	13/32	13/32	1/2	13/32
3/16	7/8	35/64	13/32	1 3/32	1 1/4	17/64	25/64	25/64	1/4	17/32	7/32	1/4	1/4	3/16	3/8	15/32	27/32	5/8	5/8	1/32	1/16	3/8	21/64	15/32	1/2	17/32	15/32	15/32	1/2	15/32
1/4	15/16	37/64	1 1/8	1 1/8	1 5/16	21/64	27/64	27/64	17/64	9/16	7/32	1/4	1/4	—	3/8	17/32	29/32	11/16	11/16	1/32	3/64	3/8	23/64	17/32	17/32	9/16	17/32	17/32	17/32	17/32
5/16	1	9/16	1 1/4	1 1/4	1 13/32	15/32	29/64	29/64	11/32	5/8	7/32	—	—	—	13/32	43/64	31/32	3/4	3/4	3/64	3/32	3/8	27/64	19/32	19/32	5/8	19/32	19/32	19/32	19/32
3/8	1 11/32	27/32	1 15/32	1 15/32	1 13/16	17/32	9/16	9/16	3/8	3/4	11/32	—	11/32	—	15/32	13/16	15/16	15/16	15/16	1/32	3/64	9/16	1/2	3/4	3/4	25/32	3/4	3/4	3/4	3/4
7/16	1 13/32	55/64	1 5/8	1 5/8	1 7/8	19/32	5/8	5/8	13/32	13/16	11/32	—	11/32	—	1/2	7/8	1 3/8	1 1/32	1 1/32	3/64	1/32	9/16	17/32	13/16	13/16	27/32	13/16	13/16	13/16	13/16
1/2	1 17/16	29/32	1 3/4	1 3/4	2	1 9/32	43/64	43/64	3/8	7/8	13/32	15/32	15/32	—	17/32	15/16	1 15/32	1 1/8	1 1/8	1/32	1/16	9/16	17/32	29/32	29/32	7/8	29/32	29/32	29/32	29/32
5/8	1 3/4	1 3/32	1 15/16	1 15/16	2 3/8	43/64	3/4	3/4	29/64	31/32	19/32	19/32	9/16	—	5/8	17/64	1 13/16	1 9/32	1 9/32	3/64	1/16	3/4	41/64	1 1/16	1 1/16	1 1/16	1 1/16	1 1/16	1 1/16	1 1/16
3/4	2	1 7/32	2 1/4	2 1/4	2 5/8	3/4	7/8	7/8	1/2	1 1/8	3/4	3/4	1 1/16	—	1 1/16	1 9/32	2	1 1/2	1 1/2	3/64	5/64	27/32	25/32	1 1/4	1 1/4	1 5/16	1 1/4	1 1/4	1 1/4	1 1/4

[a] Dryseal American (National) Standard Taper Pipe Thread unless purchaser specifically authorizes use of SAE Short Dryseal Taper Pipe Thread. See SAE Standard for Dryseal Pipe Threads, General Specifications and Tables 1 and 2.

[b] With SAE Short Pipe Thread, dimensions J, L, L_1, L_3, L_4, L_6, L_9, S_1, and U may be reduced in accordance with reduction of pipe-thread length. See SAE Standard for Dryseal Pipe Threads, Tables 3 and 4.

[c] Tap-drill depths given require use of bottoming taps to produce standard full thread length. For increased tap clearance, see Internal Taper Pipe Threads in General Specifications following Table 12.

Threaded-Sleeve Type

Details of contour are optional with the manufacturer.[4] Wrench flats are optional. The dimensions of the first figure in each group apply to all other figures in that group except as shown otherwise.

See General Specifications following Table 12.

[4] Minimum pipe-thread length where body is undercut or relieved shall not be horter than L_2 plus one turn (thread) full thread.

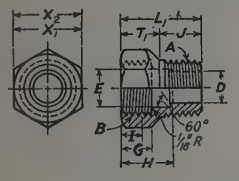


Fig. 21A

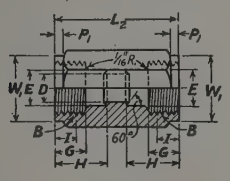


Fig. 21B

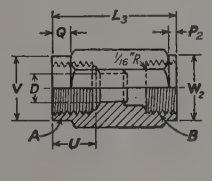


Fig. 21C

Fig. 21—Connectors and Unions

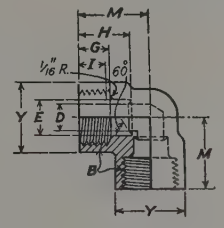


Fig. 22A

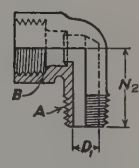


Fig. 22B

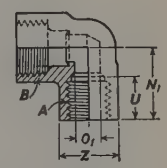


Fig. 22C

Fig. 22—Elbows

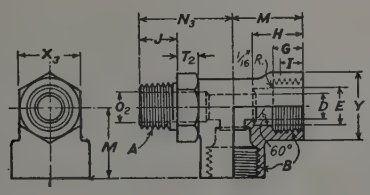


Fig. 23A

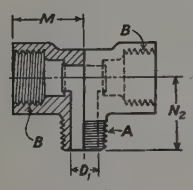


Fig. 23B

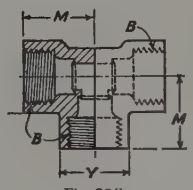


Fig. 23C

Fig. 23—Tees

TABLE 10—*Dimensions of Connectors, Unions, Elbows, and Tees (Figs. 21A-23C)*

TUBE OD ±0.002	DRYSEAL TAPER THREAD,[a] A	STRAIGHT THREAD, B	PITCH DIAM (THREAD B) Min	PITCH DIAM (THREAD B) Max	D	D_1, MAX	E Min	E Max	G, SEAT DEPTH	H	I, MIN FULL THD	J[b]	L_1[b]	L_2	L_3[b, c] ±1/32
1/8	1/8	5/16–24	0.2854	0.2902	5/64	7/32	0.128	0.132	7/32	13/32	5/32	3/8	5/8	7/8	29/32
3/16	1/8	3/8–24	0.3479	0.3528	9/64	7/32	0.191	0.195	1/4	7/16	3/16	3/8	11/16	15/16	29/32
1/4	1/8	7/16–24	0.4104	0.4153	3/16	7/32	0.253	0.257	1/4	15/32	3/16	3/8	3/4	1	29/32
5/16	1/8	1/2–20	0.4675	0.4731	7/32	7/32	0.316	0.320	9/32	15/32	13/64	3/8	7/8	1	29/32
5/16	1/4	1/2–20	0.4675	0.4731	7/32	11/32	0.316	0.320	9/32	15/32	13/64	9/16	15/16	—	—
3/8	1/4	9/16–20	0.5300	0.5355	5/16	11/32	0.378	0.382	9/32	1/2	13/64	9/16	31/32	1 1/16	1 1/8
7/16	1/4	5/8–18	0.5889	0.5949	11/32	11/32	0.442	0.446	5/16	9/16	15/64	9/16	1 3/16	1 3/16	1 7/32
1/2	3/8	11/16–16	0.6469	0.6531	13/32	13/32	0.503	0.507	3/8	21/32	9/32	9/16	1 5/16	1 3/8	1 5/16
9/16	3/8	3/4–16	0.7094	0.7159	15/32	15/32	0.566	0.570	3/8	21/32	9/32	9/16	1 11/32	1 13/32	1 5/16
5/8	1/2	7/8–18	0.8389	0.8449	1/2	9/16	0.628	0.632	3/8	21/32	5/16	3/4	1 7/16	1 13/32	1 9/16
3/4	1/2	1–20	0.9675	0.9734	19/32	19/32	0.753	0.757	7/16	3/4	3/8	3/4	1 9/16	1 19/32	—

TUBE OD ±0.002	M ±1/32	N_1[b, c] ±1/32	N_2[b] ±1/32	N_3[b] ±1/32	O_1	O_2	P_1	P_2	Q	T_1	T_2	U[b, c]	V	W_1	W_2	X_1	X_2, INT CONNECTOR	X_3	Y	Z
1/8	17/32	9/16	11/16	15/16	1/8	3/16	1/16	1/16	5/32	1/4	1/4	3/8	31/64	13/32	13/32	7/16	1/2	1/2	15/32	17/32
3/16	19/32	5/8	11/16	15/16	3/16	7/32	1/16	1/16	5/32	5/16	1/4	3/8	1/2	7/16	1/2	7/16	1/2	1/2	17/32	17/32
1/4	21/32	21/32	11/16	31/32	7/32	7/32	1/16	1/16	5/32	3/8	1/4	3/8	1/2	1/2	1/2	1/2	1/2	1/2	19/32	17/32
5/16	21/32	5/8	3/4	1	1/4	7/32	1/16	1/16	5/32	1/2	1/4	3/8	17/32	9/16	9/16	9/16	9/16	1/2	21/32	17/32
5/16	1 1/16	—	27/32	—	—	—	—	—	—	—	—	—	—	—	—	9/16	—	—	21/32	—
3/8	23/32	27/32	31/32	1 3/16	5/16	5/16	1/16	1/16	9/32	13/32	1/4	9/16	5/8	5/8	5/8	5/8	5/8	9/16	23/32	21/32
7/16	7/8	27/32	1	1 3/16	3/8	5/16	3/32	1/16	9/32	5/8	1/4	9/16	5/8	3/4	3/4	3/4	3/4	5/8	13/16	1 1/16
1/2	15/16	15/16	1	1 3/8	7/16	13/32	3/32	3/32	1/4	3/4	5/16	9/16	13/16	13/16	13/16	13/16	13/16	3/4	7/8	7/8
9/16	1 1/16	1	1 3/32	1 3/8	15/32	13/32	3/16	3/32	1/4	25/32	9/16	9/16	7/8	7/8	7/8	7/8	7/8	3/4	1	7/8
5/8	1 1/16	1 3/16	1 3/8	1 19/32	1/2	1/2	3/16	3/32	1/4	1 1/16	5/16	3/4	1 1/16	1	1 1/16	1	1 1/16	7/8	1 1/16	1 1/16
3/4	1 3/16	—	1 7/16	—	—	—	3/16	—	—	1 3/16	—	—	—	1 1/8	—	1 1/8	—	—	1 1/4	—

[a] Dryseal American (National) Standard Taper Pipe Thread unless purchaser specifically authorizes use of SAE Short Dryseal Taper Pipe Thread. See SAE Standard for Dryseal Pipe Threads, General Specifications, and Tables 1 and 2.

[b] With SAE Short Pipe Thread, dimensions J, L_1, L_2, N_1, N_2, N_3, and U may be reduced in accordance with reduction of pipe-thread length. See SAE Standard for Dryseal Pipe Threads, Tables 3 and 4.

[c] Tap-drill depths given require use of bottoming taps to produce standard full thread length. For increased tap clearance, see Internal Taper Pipe Threads in the General Specifications following Table 12.

Threaded-Sleeve Type

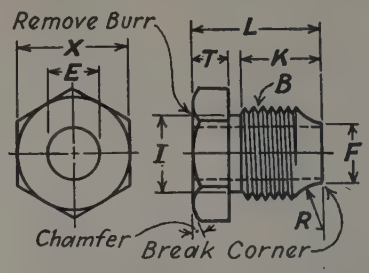


FIG. 24—COMPRESSION SCREW

TABLE 11—*Dimensions of Compression Screws (Fig. 24)*

TUBE OD ±0.002	STRAIGHT THREAD, *B*	PITCH DIAM (THREAD *B*)		*E*		*F*		*I*	*K*, FULL THD	*L*	*R*	*T*	*X*	
		Min	Max	Min	Max	Min	Max						Large Hex	Small Hex
1/8	5/16-24	0.2806	0.2843	0.128	0.132	0.155	0.160	1/4	5/16	1/2	7/32	9/64	3/8	5/16
3/16	3/8-24	0.3430	0.3468	0.191	0.195	0.220	0.225	5/16	11/32	17/32	7/32	9/64	7/16	3/8
1/4	7/16-24	0.4055	0.4093	0.253	0.257	0.290	0.295	3/8	23/64	9/16	7/32	5/32	1/2	7/16
5/16	1/2-20	0.4619	0.4662	0.316	0.320	0.350	0.355	7/16	25/64	39/64	7/32	5/32	9/16	1/2
3/8	9/16-20	0.5245	0.5287	0.378	0.382	0.420	0.425	31/64	25/64	39/64	7/32	5/32	5/8	9/16
7/16	5/8-18	0.5828	0.5875	0.442	0.446	0.482	0.487	17/32	7/16	23/32	7/32	7/32	11/16	5/8
1/2	11/16-16	0.6407	0.6455	0.503	0.507	0.550	0.555	19/32	1/2	25/32	7/16	7/32	3/4	11/16
9/16	3/4-16	0.7029	0.7079	0.566	0.570	0.605	0.610	21/32	15/32	25/32	7/16	7/32	13/16	—
5/8	7/8-18	0.8329	0.8375	0.628	0.632	0.680	0.685	25/32	1/2	25/32	7/16	7/32	1	—
3/4	1-20	0.9616	0.9661	0.753	0.757	0.810	0.815	15/16	1/2	27/32	7/16	1/4	1 1/8	—

Flared Tubes

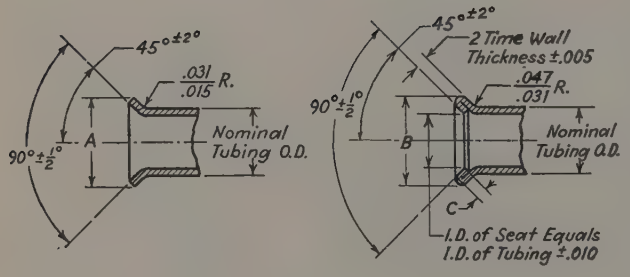


FIG. 25—SINGLE-FLARE AND DOUBLE-FLARE TUBES

TABLE 12—*Dimensions of Single- and Double-Flare Tubes (Fig. 25)*

NOMINAL TUBING OD	SINGLE FLARE DIAMETER, *A*		DOUBLE FLARE DIAMETER, *B*		SEAT LENGTH, *C*
	Max	Min	Max	Min	Min
1/8	0.181	0.171	0.213	0.203	0.040
3/16	0.249	0.239	0.280	0.270	0.040
1/4	0.325	0.315	0.360	0.350	0.040
5/16	0.404	0.388	0.425	0.415	0.062
3/8	0.487	0.471	0.500	0.490	0.062
7/16	0.561	0.545	0.570	0.560	0.062
1/2	0.623	0.607	0.640	0.630	0.062
9/16	0.676	0.660	0.712	0.698	0.062
5/8	0.748	0.732	0.772	0.758	0.062
3/4	0.916	0.900	0.912	0.898	0.062
7/8	1.041	1.025	—	—	—
1	1.157	1.141	—	—	—

General Specifications

These specifications apply to all SAE tube fittings given in Tables 1 through 12 and, with respect to pipe threads, to parts with which fittings assemble.

Pipe Threads, A—The pipe threads, unless there is specific authorization to the contrary, shall conform with the Dryseal American (National) Standard Taper Pipe Thread (NPTF). At purchaser's option, the pipe thread on fittings may be shortened in conformity with the SAE Short Dryseal Taper Pipe Thread (PTF—SAE Short). Specifications for pipe threads are given in detail in the SAE Standard for Dryseal Pipe Threads.

Tube-fitting dimensions on the preceding pages are based on the length of the Dryseal American (National) Standard Taper Pipe Thread (NPTF), because the consensus of manufacturer and user opinion is that trouble-free assembly and pressure-tight joints without lubricant or sealer cannot be assured unless a full-length thread is used.

Internal pipe threads shall be countersunk 90 deg inclusive to a diameter 0.01 in. above the major diameter.

External pipe threads shall be chamfered 45 deg to a diameter 0.01 in. below the minor diameter.

Related specifications covering blank sizes, blind-hole depths, pipe taps, chasers, tap drills, and gages are shown in the SAE Standard for Dryseal Pipe Threads.

Internal Taper Pipe Threads—The tap-drill depths and the overall lengths specified in the preceding tables for automotive tube fittings with internal taper pipe threads are not consistent with the tap-drill depths and the overall thread lengths of the Dryseal American (National) Standard Taper Pipe Threads (NPTF) specified in Table B2 of the SAE Dryseal Pipe Thread Standard. The full length Dryseal American (National) Standard Taper Pipe Taps specified in Table B4 of the SAE Dryseal Pipe Thread Standard cannot be used as the tap-drill depths and overall lengths of the fittings has been reduced to the minimum required by bottoming taps to produce standard full thread length. The deviations above described are peculiar to automotive tube fittings. As special tooling is required, caution should be exercised in specifying the deviations for any other products.

Straight Threads, B—Unified and American Standard Class 2A external and Class 2B internal threads shall be used for all types of fittings. The pitch-diameter tolerance shall be the same as the corresponding diameter-pitch combination and class of the Unified Coarse- and Fine-Thread Series. Special diameter-pitch combinations shall be based on diameter, pitch, and length of engagement of 9x pitch.

Internal threads shall be countersunk 90 deg inclusive to a diameter 0.01 in. above the major diameter.

External threads shall be chamfered 45 deg to a diameter 0.01 in. below the minor diameter.

External-Thread Eccentricity Tolerances—1. When the screw pitch diameter is maximum and the screw major diameter is maximum, these two thread elements must be concentric. However, if the screw major diameter is out-of-round, undersize, these two thread elements may be eccentric at the point of out-of-roundness an indicator reading amount equal to the screw major-diameter tolerance.

2. When the screw pitch diameter is minimum and the screw major diameter is maximum, these two thread elements may be eccentric an indicator reading amount equal to the screw pitch-diameter tolerance.

3. When the screw pitch diameter is maximum and the screw major diameter is minimum, these two thread elements may be eccentric an indicator reading amount equal to the screw major-diameter tolerance.

4. When the screw pitch diameter is minimum and the screw major diameter is minimum, these two thread elements may be eccentric an indicator reading amount equal to the sum of the screw pitch-diameter tolerance and the screw major-diameter tolerance.

Internal Thread Eccentricity Tolerances—1. When the nut pitch diameter is minimum and the nut minor diameter is minimum, these two thread elements must be concentric. However, if the nut minor diameter is out-of-round, oversize, the two thread elements may be eccentric at the point of out-of-roundness an indicator reading amount equal to the nut minor-diameter tolerance.

2. When the nut pitch diameter is maximum and the nut minor diameter is minimum, these two thread elements may be eccentric an indicator reading amount equal to the nut pitch-diameter tolerance.

3. When the nut pitch diameter is minimum and the nut minor diameter is maximum, these two thread elements may be eccentric an indicator reading amount equal to the nut minor-diameter tolerance.

4. When the nut pitch diameter is maximum and the nut minor diameter is maximum, these two thread elements may be eccentric an indicator reading amount equal to the sum of the nut pitch-diameter tolerance and the nut minor-diameter tolerance.

Material and Manufacture—Refrigeration- and marine-type fittings shall be made of nonporous close-grained forged or bar-stock brass. All other types of fittings shall be brass or steel as specified by the purchaser and, at manufacturer's option and in accordance with his process of manufacture, may be milled from the bar, cast, or forged.

Workmanship—Fittings shall be free from burrs, loose scale, sharp edges, eccentricity of diameters, and all other defects which affect their serviceability.

Finish—If steel, cadmium or zinc plate; cadmium or zinc thickness of 0.0002 in. minimum and 32-hr salt-spray test minimum.

Dimensions and Tolerances—Dimensions apply to the finished parts, plated, hardened, or otherwise processed, as specified by the purchaser. Tolerances on all dimensions not otherwise limited shall be plus or minus 0.010 in. Fitting seats must be concentric with straight-thread pitch diameters within 0.010 in. full indicator reading. Minimum and maximum across-flat dimensions shall be commercial tolerances of bar or extruded material from which the parts are made.

Details of contour are optional with the manufacturer. The dimensions of the first figure in each group apply to all other figures in that group except as shown otherwise.

The illustrations on this page apply to Table 13.

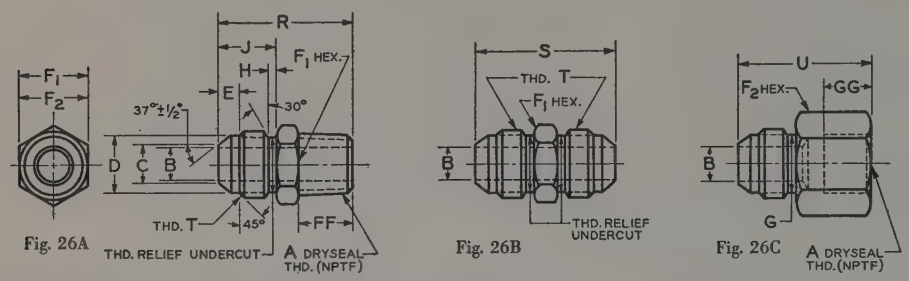


FIG. 26—CONNECTORS AND UNIONS

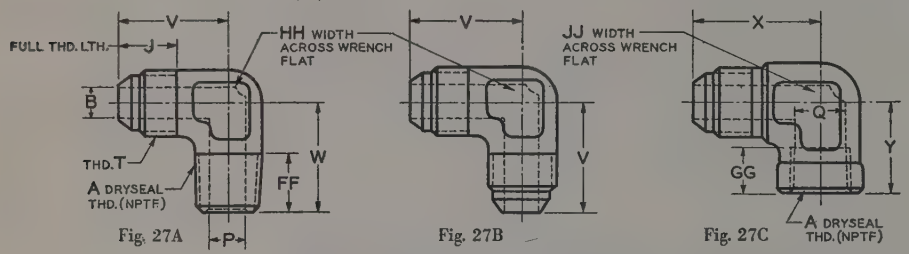


FIG. 27—90-DEG ELBOWS

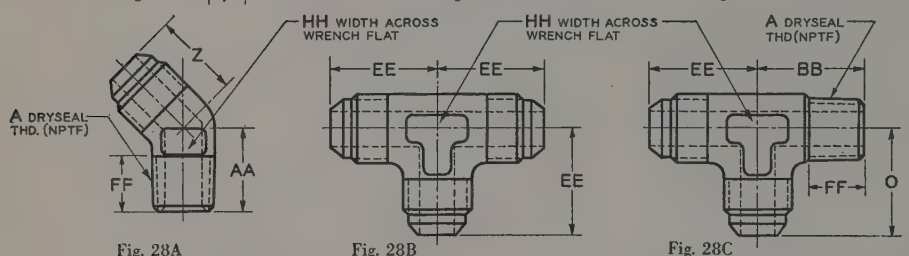


FIG. 28—45-DEG ELBOW AND TEES

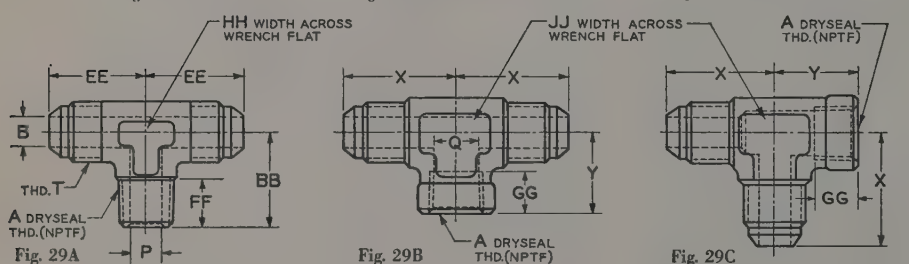


FIG. 29—TEES

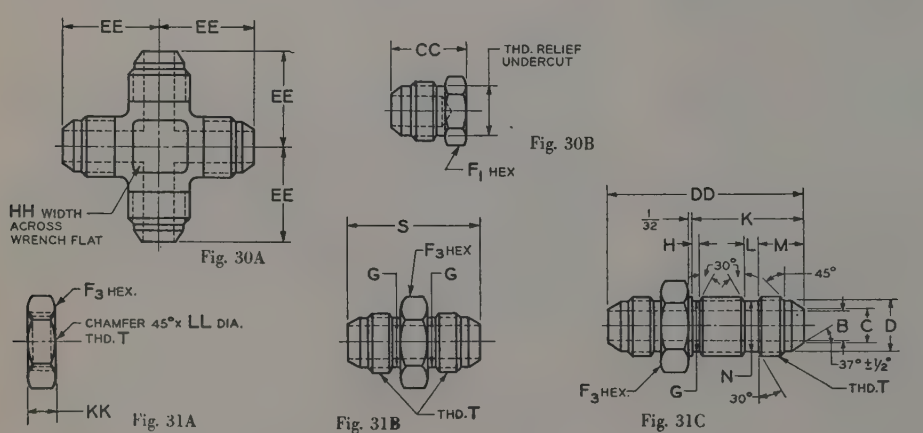


FIG. 30—CROSS AND PLUG

FIG. 31—NUT, CONNECTOR, AND BULKHEAD (FOR O-RING SEALS)

Hydraulic Tube Fittings—37-Deg Flared Type

TABLE 13—*Dimensions of Connectors, Unions, 45-Deg and 90-Deg Elbows, Tees, Cross, Plug, Bulkhead, and Nut (Figs. 26A–31C)*

TUBE OD	*A* DRYSEAL TAPER THREAD	STRAIGHT THREAD, *T*	STRAIGHT THD *T*, PITCH DIAM				*B*, DRILL	*C* ±0.003 DIAM	*D* ±0.003 DIAM	*E* +0.015 −0.000 DIAM	F_1	F_2	F_3
			External		Internal								
			Max	Min	Min	Max							
1/8	1/8	5/16-24	0.2843	0.2806	0.2854	0.2902	0.062 ± 0.003	0.083	0.251	0.177	7/16	9/16	9/16
3/16	1/8	3/8-24	0.3468	0.3430	0.3479	0.3528	0.125 ± 0.003	0.146	0.313	0.177	7/16	9/16	5/8
1/4	1/8	7/16-20	0.4037	0.3995	0.4050	0.4104	0.172 ± 0.003	0.193	0.365	0.193	1/2	9/16	11/16
5/16	1/8	1/2-20	0.4662	0.4619	0.4675	0.4731	0.234 ± 0.003	0.255	0.427	0.193	9/16	9/16	3/4
3/8	1/4	9/16-18	0.5250	0.5205	0.5264	0.5323	0.297 ± 0.004	0.318	0.482	0.198	5/8	3/4	13/16
1/2	3/8	3/4-16	0.7079	0.7029	0.7094	0.7159	0.391 ± 0.004	0.426	0.661	0.253	13/16	7/8	1
5/8	1/2	7/8-14	0.8270	0.8216	0.8286	0.8356	0.484 ± 0.004	0.539	0.774	0.266	15/16	1 1/8	1 1/8
3/4	3/4	1 1/16-12	1.0067	1.0010	1.0084	1.0158	0.609 ± 0.005	0.664	0.945	0.315	1 1/8	1 3/8	1 3/8
7/8	3/4	1 3/16-12	1.1317	1.1259	1.1334	1.1409	0.718 ± 0.005	0.788	1.070	0.315	1 1/4	1 3/8	1 1/2
1	1	1 5/16-12	1.2567	1.2509	1.2584	1.2659	0.844 + 0.007 − 0.005	0.913	1.195	0.315	1 3/8	1 5/8	1 5/8
1 1/4	1 1/4	1 5/8-12	1.5691	1.5632	1.5709	1.5785	1.078 + 0.008 − 0.005	1.147	1.507	0.367	1 11/16	2	1 7/8
1 1/2	1 1/2	1 7/8-12	1.8191	1.8131	1.8209	1.8287	1.312 + 0.008 − 0.005	1.381	1.757	0.378	2	2 5/16	2 1/8
2	2	2 1/2-12	2.4440	2.4378	2.4459	2.4540	1.781 + 0.010 − 0.005	1.880	2.382	0.461	2 5/8	2 7/8	2 3/4

TUBE OD	*G* +0.002 −0.003 DIAM	*H* +0.015 −0.000 DIAM	*J* ±0.015	*K*	*L* +0.010 −0.000	*M* ±0.005	*N* +0.000 −0.003 DIAM	*P*, DRILL	*Q*, TAP DRILL	*R*	*S*	*U*	*V* +3/64 −1/64
1/8	0.250	0.063	0.448	1 7/64	0.125	0.385	0.250	3/16	5/16	1 1/64	1 7/32	1 3/32	49/64
3/16	0.313	0.063	0.479	1 7/64	0.131	0.385	0.313	3/16	5/16	1 3/64	1 7/32	1 3/32	53/64
1/4	0.364	0.075	0.550	1 13/64	0.140	0.443	0.364	3/16	5/16	1 7/64	1 1/4	1 5/32	57/64
5/16	0.427	0.075	0.550	1 13/64	0.140	0.443	0.427	3/16	5/16	1 9/64	1 1/4	1 3/16	61/64
3/8	0.482	0.083	0.556	1 9/32	0.156	0.476	0.482	9/32	13/32	1 3/8	1 3/8	1 5/16	1 1/16
1/2	0.660	0.094	0.657	1 7/16	0.187	0.565	0.660	13/32	35/64	1 1/2	1 9/16	1 17/32	1 1/4
5/8	0.773	0.107	0.758	1 37/64	0.219	0.623	0.773	17/32	43/64	1 53/64	1 53/64	1 13/16	1 29/64
3/4	0.945	0.125	0.864	1 3/4	0.234	0.732	0.945	23/32	7/8	1 61/64	2 7/64	2	1 21/32
7/8	1.070	0.125	0.890	1 3/4	0.234	0.732	1.070	23/32	7/8	2 1/16	2 5/32	2	1 23/32
1	1.195	0.125	0.911	1 3/4	0.234	0.732	1.195	15/16	1 7/64	2 7/32	2 3/16	2 7/32	1 13/16
1 1/4	1.507	0.125	0.958	1 51/64	0.234	0.784	1.507	1 1/4	1 29/64	2 23/64	2 9/32	2 15/32	2 1/16
1 1/2	1.756	0.125	1.083	1 13/16	0.234	0.795	1.756	1 1/2	1 11/16	2 37/64	2 17/32	2 9/16	2 21/64
2	2.381	0.125	1.333	2 3/32	0.234	0.878	2.381	1 15/16	2 11/64	3 7/64	3 1/16	2 29/32	3 1/16

TUBE OD	*W* +3/64 −1/64	*X* +3/64 −1/64	*Y* +3/64 −1/64	*Z* +3/64 −1/64	*AA* +3/64 −1/64	*BB* +3/64 −1/64	*CC*	*DD*	*EE* +3/64 −1/64	*FF*, MIN	*GG*	*HH*	*JJ*	*KK*	*LL* +1/64 −0 DIAM
1/8	23/32	63/64	41/64	41/64	1/2	11/16	41/64	1 53/64	47/64	3/8	5/16	5/16	9/16	7/32	5/16
3/16	23/32	1 1/64	41/64	41/64	1/2	11/16	43/64	1 55/64	51/64	3/8	5/16	3/8	9/16	7/32	3/8
1/4	25/32	1 1/16	41/64	45/64	5/8	3/4	47/64	2 3/64	55/64	3/8	5/16	7/16	9/16	1/4	7/16
5/16	25/32	1 1/16	41/64	3/4	5/8	3/4	49/64	2 3/64	59/64	3/8	5/16	1/2	9/16	1/4	1/2
3/8	1 3/32	1 7/32	57/64	1 3/16	27/32	1 1/16	1 3/16	2 7/32	1 1/32	9/16	25/64	9/16	3/4	1 7/64	9/16
1/2	1 7/32	1 13/32	31/32	31/32	15/16	1 3/16	1 5/16	2 29/64	1 7/32	9/16	7/16	3/4	7/8	5/16	3/4
5/8	1 15/32	1 5/8	1 15/64	1 3/32	1 5/32	1 7/16	1 7/64	2 23/32	1 27/64	3/4	37/64	7/8	1 1/16	23/64	7/8
3/4	1 19/32	1 7/8	1 11/32	1 17/64	1 3/16	1 9/16	1 13/64	3 1/32	1 5/8	3/4	1 9/32	1 1/16	1 5/16	1 3/32	1 1/16
7/8	1 11/16	1 27/32	1 11/32	1 3/8	1 1/4	1 5/8	1 15/64	3 1/16	1 23/32	3/4	1 9/32	1 3/16	1 5/16	1 3/32	1 3/16
1	1 31/32	2 5/32	1 5/8	1 29/64	1 15/32	1 15/16	1 9/32	3 5/64	1 25/32	15/16	45/64	1 5/16	1 5/8	1 3/32	1 5/16
1 1/4	2 3/8	2 5/16	1 11/16	1 37/64	1 21/32	2 11/32	1 23/64	3 5/32	2 1/32	31/32	2 3/32	1 5/8	1 7/8	1 3/32	1 5/8
1 1/2	2 5/8	2 7/8	2 1/16	1 49/64	1 3/4	2 5/8	1 31/64	3 5/16	2 19/64	1	2 3/32	1 7/8	2 9/16	1 3/32	1 7/8
2	3	3 3/32	2 3/8	2 13/64	2 3/32	2 31/32	1 47/64	3 53/64	3 1/32	1 1/32	3/4	2 1/2	2 13/16	1 3/32	2 1/2

Hydraulic Tube Fittings—37-Deg Flared Type

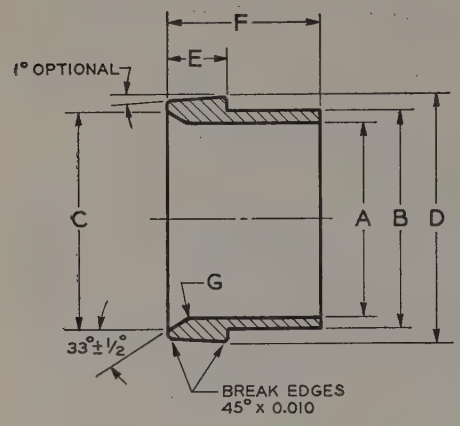


FIG. 32—SLEEVE, THREE-PIECE ASSEMBLY

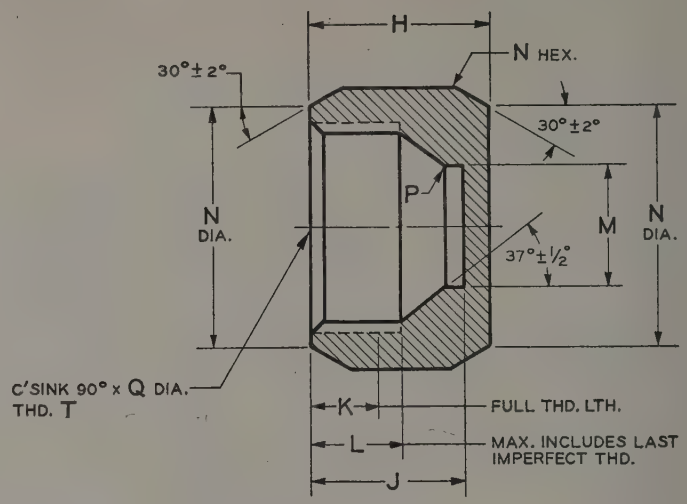


FIG. 33—CAP—OUTSIDE CONTOUR OPTIONAL WITH MANUFACTURER

TABLE 14—*Dimensions of Sleeve of Three-Piece Assembly and Cap (Figs. 32 and 33)*

TUBE OD	STRAIGHT THREAD, T	STR. THD, T, PITCH DIAM				A +0.003 −0.000 DIAM	B +0.000 −0.003 DIAM	C ±0.005 DIAM	D +0.000 −0.003 DIAM	E	F	G, RAD	H	J	K ±0.005	L ±0.005	M, DIAM	N	P, RAD	Q +1/64 −0 DIAM
		External		Internal																
		Max	Min	Min	Max															
1/8	5/16-24	0.2843	0.2806	0.2854	0.2902	0.130	0.172	0.205	0.267	1/8	11/32	1/32	1/2	7/16	0.172	0.234	1/16	3/8	1/32	5/16
3/16	3/8-24	0.3468	0.3430	0.3479	0.3528	0.193	0.234	0.267	0.329	9/64	11/32	1/32	9/16	1/2	0.203	0.266	1/8	7/16	1/32	3/8
1/4	7/16-20	0.4037	0.3995	0.4050	0.4104	0.255	0.297	0.315	0.383	9/64	13/32	1/32	19/32	17/32	0.250	0.328	11/64	9/16	1/32	7/16
5/16	1/2-20	0.4662	0.4619	0.4675	0.4731	0.318	0.366	0.375	0.445	5/32	7/16	1/32	39/64	35/64	0.266	0.344	15/64	5/8	1/32	1/2
3/8	9/16-18	0.5250	0.5205	0.5264	0.5323	0.380	0.432	0.441	0.502	11/64	1/2	3/64	5/8	9/16	0.266	0.344	19/64	11/16	1/16	9/16
1/2	3/4-16	0.7079	0.7029	0.7094	0.7159	0.505	0.562	0.589	0.682	7/32	9/16	1/16	3/4	5/8	0.281	0.375	25/64	7/8	1/16	3/4
5/8	7/8-14	0.8270	0.8216	0.8286	0.8356	0.631	0.690	0.705	0.797	15/64	21/32	1/16	27/32	23/32	0.359	0.469	31/64	1	1/16	7/8
3/4	1 1/16-12	1.0067	1.0010	1.0084	1.0158	0.756	0.826	0.880	0.972	17/64	1 1/16	5/64	29/32	25/32	0.375	0.500	39/64	1 1/4	1/16	1 1/16
7/8	1 3/16-12	1.1317	1.1259	1.1334	1.1409	0.881	0.953	1.005	1.097	17/64	3/4	3/32	31/32	27/32	0.406	0.531	23/32	1 3/8	1/16	1 3/16
1	1 5/16-12	1.2567	1.2509	1.2584	1.2659	1.006	1.081	1.130	1.222	9/32	25/32	3/32	1 1/64	55/64	0.438	0.563	27/32	1 1/2	1/16	1 5/16
1 1/4	1 5/8-12	1.5691	1.5632	1.5709	1.5785	1.260	1.339	1.412	1.534	5/16	29/32	3/32	1 1/16	29/32	0.438	0.563	1 5/64	2	1/16	1 5/8
1 1/2	1 7/8-12	1.8191	1.8131	1.8209	1.8287	1.510	1.609	1.630	1.784	11/32	1 1/8	7/64	1 3/16	1 1/32	0.531	0.656	1 5/16	2 1/4	1/16	1 7/8
2	2 1/2-12	2.4440	2.4378	2.4459	2.4540	2.014	2.159	2.195	2.409	13/32	1 3/16	7/64	1 7/16	1 9/32	0.703	0.828	1 25/32	2 7/8	1/16	2 1/2

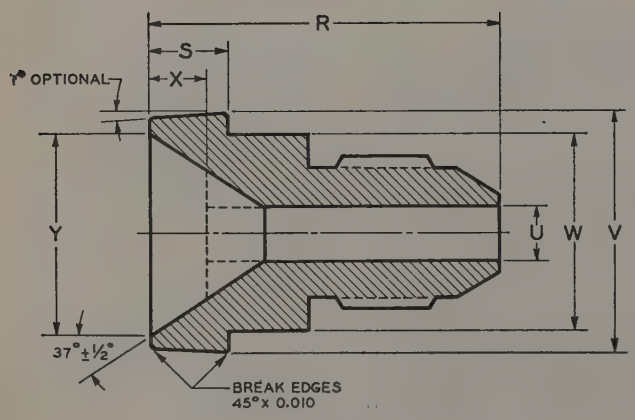


FIG. 34—REDUCING ADAPTER

TABLE 15—*Dimensions of Reducing Adapter (Fig. 34)*

TUBE REDUCTION	R	S	U REF DIAM	V +0.000 −0.003 DIAM	W +0.000 −0.003 DIAM	X	Y +0.005 −0.015 DIAM
3/8-1/4	31/32	11/64	0.172	0.502	0.432	—	0.441
1/2-1/4	1	7/32	0.172	0.682	0.562	—	0.589
1/2-3/8	1	7/32	0.297	0.682	0.562	—	0.589
5/8-1/4	1 1/32	15/64	0.172	0.797	0.690	—	0.705
5/8-3/8	1 1/32	15/64	0.297	0.797	0.690	—	0.705
3/4-1/4	1 3/32	17/64	0.172	0.972	0.826	13/32	0.880
3/4-3/8	1 3/32	17/64	0.297	0.972	0.826	—	0.880
3/4-1/2	1 5/16	17/64	0.391	0.972	0.826	—	0.880
1-3/4	1 15/32	9/32	0.609	1.222	1.081	—	1.130

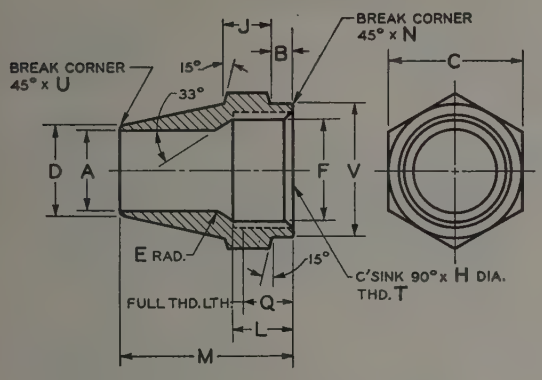


FIG. 35—NUT, TWO-PIECE ASSEMBLY

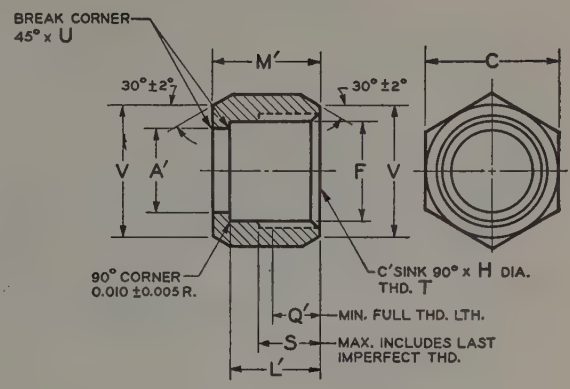


FIG. 36—NUT, THREE-PIECE ASSEMBLY

TABLE 16—*Dimensions of Nuts for Two-Piece and Three-Piece Assemblies (Figs. 35 and 36)*

TUBE OD	STRAIGHT THREAD, T	STR THD, T, PITCH DIAM Internal Min	STR THD, T, PITCH DIAM Internal Max	A +0.003 −0.000 DIAM	A¹ +0.003 −0.000 DIAM	B	C, MIN	D +0.005 −0.000 DIAM	E	F +0.005 −0.000 DIAM	H +1/64 −0 DIAM	J	L ±0.005	L¹ ±0.010	M	M¹	N ±0.005	Q ±0.005	Q¹ ±0.005	S +0.015 −0.005	U ±0.005	V
1/8	5/16-24	0.2854	0.2902	0.130	0.180	3/32	3/8	0.183	1/32	0.272	5/16	1/4	0.282	0.460	2 7/32	1 7/32	0.010	0.220	0.251	0.313	0.005	3/8
3/16	3/8-24	0.3479	0.3528	0.193	0.242	3/32	7/16	0.246	1/32	0.334	3/8	1 17/64	0.313	0.506	1 5/16	1 9/32	0.010	0.251	0.282	0.344	0.005	7/16
1/4	7/16-20	0.4050	0.4104	0.255	0.305	3/32	9/16	0.308	1/32	0.388	7/16	2 1/64	0.375	0.532	1	3 9/64	0.010	0.300	0.300	0.375	0.005	9/16
5/16	1/2-20	0.4675	0.4731	0.318	0.374	3/32	5/8	0.371	1/32	0.451	1/2	2 1/64	0.375	0.579	1 1/16	4 3/64	0.010	0.300	0.331	0.406	0.005	5/8
3/8	9/16-18	0.5264	0.5323	0.380	0.440	3/32	1 1/16	0.433	3/64	0.508	9/16	1 1/32	0.385	0.603	1 3/32	2 3/32	0.010	0.302	0.333	0.416	0.010	1 1/16
1/2	3/4-16	0.7094	0.7159	0.505	0.570	1/8	7/8	0.558	1/16	0.688	3/4	2 9/64	0.438	0.723	1 9/32	2 7/32	0.010	0.344	0.375	0.469	0.010	7/8
5/8	7/8-14	0.8286	0.8356	0.631	0.698	3/16	1	0.694	1/16	0.804	7/8	3 3/64	0.521	0.817	1 31/64	3 1/32	0.010	0.414	0.461	0.568	0.010	1
3/4	1 1/16-12	1.0084	1.0158	0.756	0.834	3/16	1 1/4	0.829	5/64	0.979	1 1/16	4 1/64	0.594	0.868	1 21/32	1 1/64	0.010	0.469	0.469	0.594	0.010	1 1/4
7/8	1 3/16-12	1.1334	1.1409	0.881	0.961	3/16	1 3/8	0.964	3/32	1.104	1 3/16	1 1/16	0.594	0.914	1 13/16	1 5/64	0.010	0.469	0.516	0.640	0.010	1 3/8
1	1 5/16-12	1.2584	1.2659	1.006	1.089	3/16	1 1/2	1.099	3/32	1.229	1 5/16	4 7/64	0.625	0.962	1 15/16	1 1/8	0.010	0.500	0.563	0.688	0.010	1 1/2
1 1/4	1 5/8-12	1.5709	1.5785	1.260	1.347	1/4	2	1.353	3/32	1.541	1 5/8	4 7/64	0.625	1.017	2 3/16	1 7/32	0.010	0.500	0.563	0.688	0.010	2
1 1/2	1 7/8-12	1.8209	1.8287	1.510	1.617	1/4	2 1/4	1.603	7/64	1.791	1 7/8	5 3/64	0.708	1.170	2 5/16	1 1 3/32	0.010	0.583	0.661	0.786	0.010	2 1/4
2	2 1/2-12	2.4459	2.4540	2.014	2.167	5/16	2 7/8	2.127	7/64	2.416	2 1/2	5 9/64	0.875	1.462	2 3/4	1 47/64	0.015	0.750	0.844	0.969	0.015	2 7/8

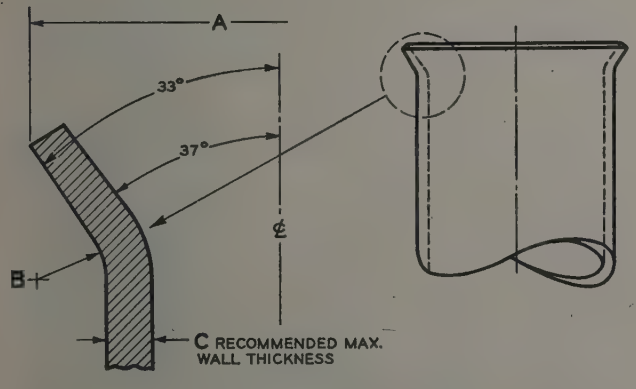


FIG. 37—SINGLE-FLARE TUBE

TABLE 17—*Dimensions of Single-Flare Tubes (Fig. 37)*

TUBE SIZE NOM OD	A, DIAM Max	A, DIAM Min	B ±0.010 RAD	C, MAX
1/8	0.224	0.214	0.032	0.035
3/16	0.290	0.280	0.032	0.035
1/4	0.359	0.349	0.032	0.065
5/16	0.421	0.411	0.032	0.065
3/8	0.484	0.474	0.046	0.065
1/2	0.656	0.646	0.062	0.083
5/8	0.781	0.771	0.062	0.095
3/4	0.937	0.927	0.078	0.109
7/8	1.062	1.052	0.078	0.109
1	1.187	1.172	0.093	0.120
1 1/4	1.500	1.485	0.093	0.120
1 1/2	1.721	1.706	0.109	0.120
2	2.356	2.341	0.109	0.134

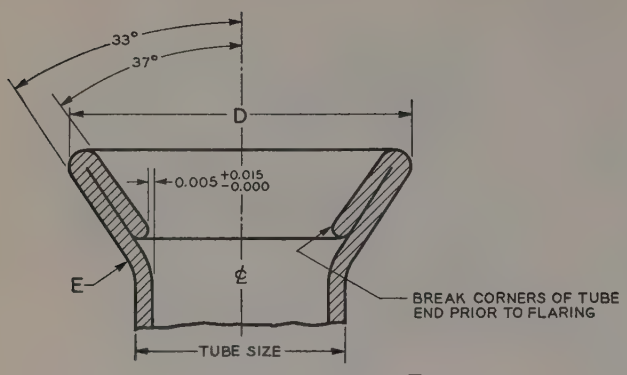


FIG. 38—DOUBLE-FLARE TUBE

TABLE 18—*Dimensions of Double-Flare Tubes (Fig. 38)*

TUBE SIZE NOM OD	D, DIAM		E ±0.010 RAD
	Max	Min	
1/8	0.224	0.214	0.032
3/16	0.302	0.292	0.032
1/4	0.359	0.349	0.032
5/16	0.421	0.411	0.032
3/8	0.484	0.474	0.046

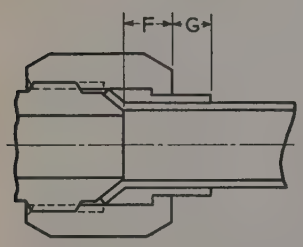


FIG. 39—THREE-PIECE TUBE ASSEMBLY

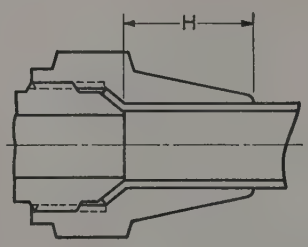


FIG. 40—TWO-PIECE TUBE ASSEMBLY

TABLE 19—*Dimensions of Two-Piece and Three-Piece Assemblies (Figs. 39 and 40)*

TUBE OD	F	G	H
1/8	3/16	1/8	31/64
3/16	1/4	1/8	9/16
1/4	3/16	11/64	19/32
5/16	19/64	7/64	21/32
3/8	9/32	3/16	11/16
1/2	5/16	3/16	13/16
5/8	3/8	17/64	15/16
3/4	23/64	1/4	1 1/32
7/8	3/8	5/16	1 3/16
1	11/32	13/32	1 5/16
1 1/4	11/32	25/64	1 1/2
1 1/2	1/2	35/64	1 17/32
2	35/64	17/32	1 3/4

General Specifications

These specifications apply to hydraulic tube fittings of the 37-deg flared type given in Tables 13 through 19 and Figs. 26 through 40.

Types and Styles—The fittings shall be as shown in Figs. 26 through 40 and Tables 13 through 19. The basic design of these fittings is derived from Air Force and Navy Aeronautical Standard for 37-deg flared fittings. Since the Air Force and Navy Aeronautical fittings meet a performance specification, any changes which may be made should not be detrimental to the design or performance.

Dimensions and Tolerances—Dimensions apply to the finished parts, plated or otherwise processed, as specified by the purchaser. Tolerances on all dimensions not otherwise limited shall be plus or minus 1/64 in. Fitting seats must not be concentric with straight-thread pitch diameters within 0.010 in. full indicator reading. Minimum and maximum across-flat dimensions shall be commercial tolerance of bar or extruded stock from which the parts are made.

Passages—Drilled passages through fittings shall be as specified in the tables. Where straight fittings are machined from opposite ends, an offset of 0.015 is allowable at the meeting point. On angle fittings, the cross-sectional area at the junction of the fluid passages shall not be smaller than the cross-sectional area of the smaller passage.

Wall Thickness—The wall thickness at any point on the fitting shall not be less than the thickness established by the dimensions and tolerances for inside and outside diameter and eccentricities specified by the tables.

Threads—Straight threads shall be Unified and American Standard Class 2A external and Class 2B internal (Unified fine, UNF; American fine, NF; and American 12-thread series).

Pipe Threads—Pipe threads, unless there is specific authorization to the contrary, shall conform to the Dryseal American (National) Standard Taper Pipe Thread (NPTF).

External threads shall be chamfered 45 deg to a diameter 0.01 in. below the minor diameter.

Internal threads shall be chamfered 45 deg to a diameter 0.01 in. above the major diameter.

Related specifications covering blank sizes, blind-hole depths, pipe taps, chasers, tap drills, and gages are shown in the SAE Standard for Dryseal Pipe Threads.

Material—Fittings shall be close-grained nonporous forged or bar-stock material.

Workmanship—Fittings shall be free from burrs, loose scale, sharp edges, and all other defects which affect their serviceability. All sealing surfaces shall be smooth except that annular tool marks up to 100 microinches rms maximum will be permissible. Workmanship shall conform to the best commercial practice to produce high-quality fittings.

Finish—If steel, cadmium or zinc plate; cadmium or zinc thickness of 0.0002 in. minimum and 32-hr salt-spray test minimum.

Automotive Pipe Fittings

SAE Standard

Report of Parts and Fittings Technical Committee approved February 1948 and last revised by Tube, Pipe, Hose, and Lubrication Fittings Technical Committee April 1951.

Fittings for Steel, Brass, Bronze, and Aluminum Alloys

Details of contour are optional with manufacturer.

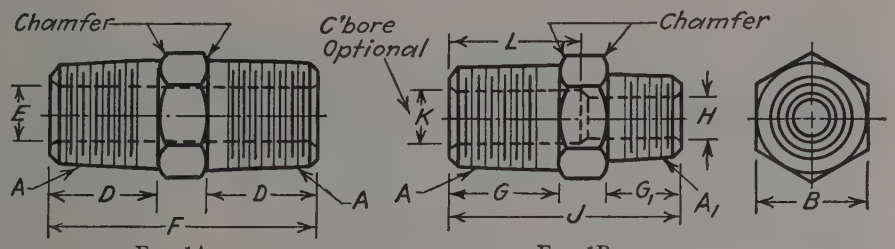


FIG. 1A FIG. 1B

FIG. 1—NIPPLES AND REDUCER NIPPLES

TABLE 1—*Dimensions of Nipples and Reducer Nipples (Fig. 1)*

DRYSEAL TAPER THREAD		HEX WIDTH	NIPPLES			REDUCER NIPPLES					
Nipples	Reducer nipples		Shoulder length	Maximum hole diameter	Overall length	Shoulder length		Maximum hole diameter	Overall length	Optional counterbore	
										Diam	Depth
A	*A* x *A*1	*B*	*D*	*E*	*F*	*G*	*G*1	*H*	*J*	*K*	*L*
1/16–27	—	5/16	3/8	9/64	15/16	—	—	—	—	—	—
1/8 –27	1/8 x 1/16	7/16	3/8	7/32	31/32	3/8	3/8	5/32	31/32	3/16	15/32
1/4 –18	1/4 x 1/8	9/16	9/16	5/16	1 3/8	9/16	3/8	7/32	1 3/16	9/32	11/16
3/8 –18	3/8 x 1/8	11/16	9/16	7/16	1 13/32	9/16	3/8	7/32	1 7/32	13/32	11/16
—	3/8 x 1/4	11/16	—	—	—	9/16	9/16	5/16	1 13/32	13/32	11/16
1/2 –14	1/2 x 3/8	7/8	3/4	9/16	1 13/16	3/4	9/16	7/16	1 5/8	17/32	29/32

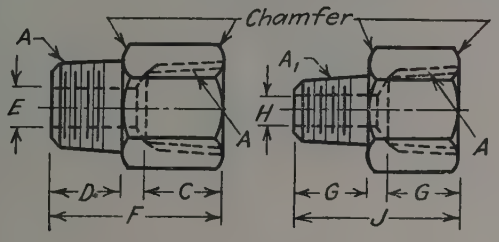


FIG. 2A FIG. 2B

FIG. 2—ADAPTER AND REDUCER ADAPTER

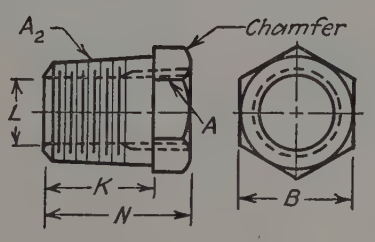


FIG. 3—REDUCER BUSHING

TABLE 2—*Dimensions of Adapters, Reducer Adapters, and Reducer Bushings (Figs. 2 and 3)*

DRYSEAL TAPER THREAD			HEX WIDTH	TAP-DRILL DEPTH	ADAPTERS			REDUCER ADAPTERS			REDUCER BUSHINGS		
Adapter	Reducer adapter	Reducer bushing			Shoulder length	Maximum hole diameter	Overall length	Shoulder length	Maximum hole diameter	Overall length	Shoulder length	Maximum hole diameter	Overall length
A	*A* x *A*1	*A*2 x *A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	*L*	*N*
1/16–27	—	1/8 x 1/16	7/16	3/8	3/8	9/64	27/32	—	—	—	3/8	1/4	9/16
1/8 –27	1/8 x 1/16	1/4 x 1/8	9/16	3/8	3/8	7/32	7/8	3/8	5/32	27/32	9/16	21/64	3/4
—	—	3/8 x 1/8	11/16	—	—	—	—	—	—	—	9/16	21/64	3/4
1/4 –18	1/4 x 1/8	3/8 x 1/4	3/4	9/16	9/16	5/16	1 1/4	3/8	7/32	1 1/16	9/16	7/16	3/4
—	—	1/2 x 1/8	7/8	—	—	—	—	—	—	—	3/4	21/64	1
3/8 –18	3/8 x 1/4	1/2 x 1/4	7/8	9/16	9/16	7/16	1 1/4	9/16	5/16	1 1/4	3/4	7/16	1
—	—	1/2 x 3/8	7/8	—	—	—	—	—	—	—	3/4	9/16	1
1/2 –14	1/2 x 3/8	—	1 1/16	3/4	3/4	9/16	1 21/32	9/16	7/16	1 15/32	—	—	—
3/4 –14	3/4 x 1/2	—	1 3/8	3/4	3/4	3/4	1 11/16	3/4	9/16	1 11/16	—	—	—
1 –11 1/2	1 x 3/4	—	1 5/8	15/16	15/16	31/32	2 1/16	3/4	3/4	1 7/8	—	—	—

Fittings for Steel, Brass, Bronze, and Aluminum Alloys

Details of contour are optional with manufacturer.

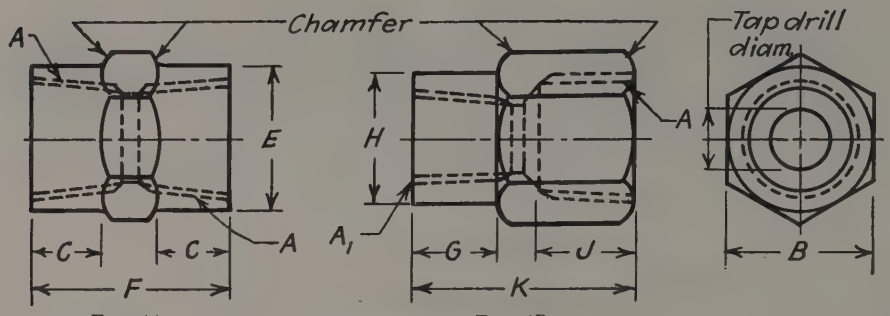


FIG. 4A FIG. 4B

FIG. 4—COUPLINGS AND REDUCER COUPLINGS

TABLE 3—*Dimensions of Couplings and Reducer Couplings (Fig. 4)*

DRYSEAL TAPER THREAD		HEX WIDTH	COUPLINGS			REDUCER COUPLINGS			
Coupling	Reducer coupling		Shoulder length	Minimum body diameter	Overall length	Shoulder length	Minimum body diameter	Tap-drill depth	Overall length
A	*A* x *A*1	*B*	*C*	*E*	*F*	*G*	*H*	*J*	*K*
1/16–27	—	7/16	9/32	7/16	3/4	—	—	—	—
1/8 –27	1/8 x 1/16	9/16	17/64	9/16	3/4	5/16	1/2	3/8	25/32
1/4 –18	1/4 x 1/8	3/4	7/16	3/4	1 1/8	5/16	9/16	9/16	31/32
3/8 –18	3/8 x 1/8	7/8	21/64	7/8	1 1/8	1/4	9/16	9/16	15/16
—	3/8 x 1/4	7/8	—	—	—	15/32	3/4	9/16	1 5/32
1/2 –14	1/2 x 1/8	1 1/16	19/32	1 1/16	1 1/2	1/4	9/16	3/4	1 3/16
—	1/2 x 1/4	1 1/16	—	—	—	11/32	3/4	3/4	1 9/32
—	1/2 x 3/8	1 1/16	—	—	—	7/16	7/8	3/4	1 3/8

Fittings for Cast Iron, Malleable Iron, and Cast Brass

Details of contour are optional with manufacturer. Wrench flats are optional.

(Minimum pipe-thread length where body is undercut or relieved shall not be shorter than L_2 plus one turn (thread) full thread.)

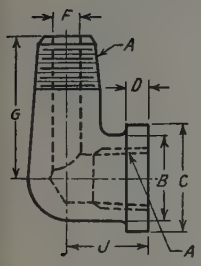


Fig. 5A

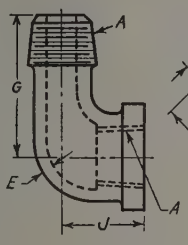


Fig. 5B

Fig. 5—90-Deg Street Elbows

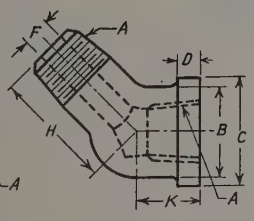


Fig. 6A

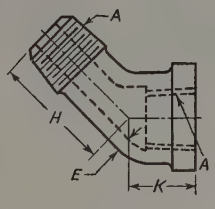


Fig. 6B

Fig. 6—45-Deg Street Elbows

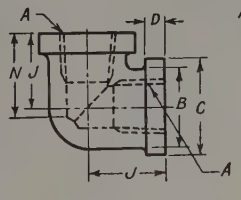


Fig. 7A

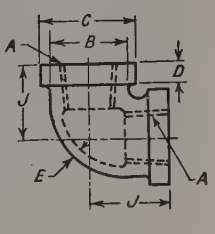


Fig. 7B

Fig. 7—90-Deg Pipe Elbows

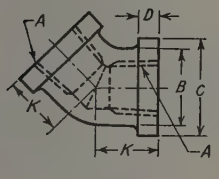


Fig. 8A

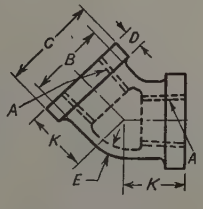


Fig. 8B

Fig. 8—45 Deg Pipe Elbows

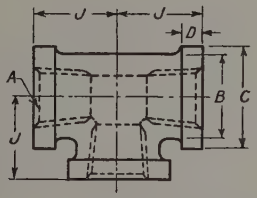


Fig. 9A

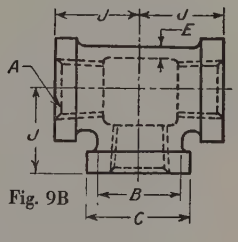


Fig. 9B

Fig. 9—Tees

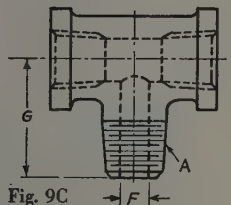


Fig. 9C

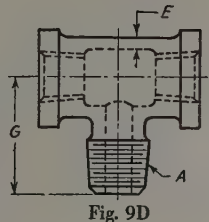


Fig. 9D

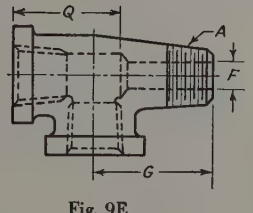


Fig. 9E

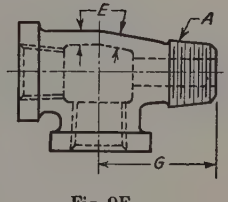


Fig. 9F

Fig. 9—Tees

TABLE 4—*Dimensions of 90-Deg and 45-Deg Street Elbows, Pipe Elbows, and Tees*[a] (*Figs. 5A-9F*)

FIGS.	DRYSEAL TAPER THREAD	MINIMUM BODY DIAMETER	MINIMUM COLLAR DIAMETER	MINIMUM COLLAR THICKNESS	MINIMUM WALL THICKNESS	MAXIMUM HOLE DIAMETER	90- AND 45-DEG STREET ELBOWS AND TEES		90- AND 45-DEG STREET ELBOWS, PIPE ELBOWS, AND TEES		
							Center to end (ext thd)		Center to end (int thd)		Tap-drill depth
							90 deg and tees	45 deg	90 deg and tees	45 deg	Tees
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	*Q*
5A, 6A, 7A, 8A, and 9A.....	1/16-27	7/16	17/32	1/8	5/64	9/64	13/16	11/16	1/2	13/32	21/32
5A, 6A, 7A, 8A, and 9A.....	1/8-27	9/16	43/64	9/64	5/64	7/32	59/64	25/32	35/64	27/64	3/4
5A, 6A, 7A, 8A, and 9A.....	1/4-18	23/32	13/16	5/32	5/64	5/16	1 7/64	7/8	23/32	9/16	31/32
5B, 6B, 7B, 8B, and 9B.....	3/8-18	7/8	1	11/64	3/32	7/16	1 1/4	59/64	53/64	5/8	—
5B, 6B, 7B, 8B, and 9B.....	1/2-14	1 1/32	1 11/64	3/16	3/32	9/16	1 1/2	1 1/16	1 1/64	25/32	—

[a] 1/16, 1/8, and 1/4 nominal sizes—Figs. 5A, 6A, 7A, 8A, 9A, 9C, and 9E are solid castings with drilled passage hole.
3/8 and 1/2 nominal sizes—Figs. 5B, 6B, 7B, 8B, 9B, 9D, and 9F are cored castings with cored passage hole.
Tolerance for center to end dimensions—nominal size, 1/16 1/8 1/4 3/8 1/2
tolerance + or −, 0.03 0.03 0.04 0.05 0.06

Fittings for Bar-Stock Brass, Bronze, Steel, and Aluminum Alloys

Details of contour are optional with manufacturer.

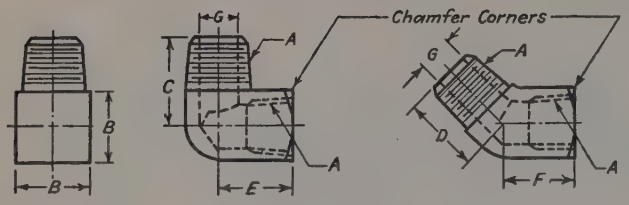


FIG. 10A FIG. 10B

FIG. 10—90-DEG AND 45-DEG STREET ELBOWS

TABLE 5—*Dimensions of 90-Deg and 45-Deg Street Elbows (Fig. 10)*

DRYSEAL TAPER THREAD	BODY SIZE	CENTER TO END				MAXIMUM HOLE DIAMETER
		External thread		Internal thread		
		90 deg	45 deg	90 deg	45 deg	
A	*B*	*C*	*D*	*E*	*F*	*G*
1/16–27	7/16	19/32	15/32	29/64	3/8	9/64
1/8 –27	1/2	5/8	1/2	35/64	3/8	7/32
1/4 –18	11/16	29/32	23/32	25/32	9/16	5/16
3/8 –18	13/16	31/32	25/32	27/32	9/16	7/16
1/2 –14	1	1 1/4	1	1 3/32	3/4	9/16
3/4 –14	1 1/4	1 3/8	1 1/16	1 5/32	3/4	3/4
1 –11 1/2	1 1/2	1 11/16	1 11/32	1 33/64	15/16	31/32

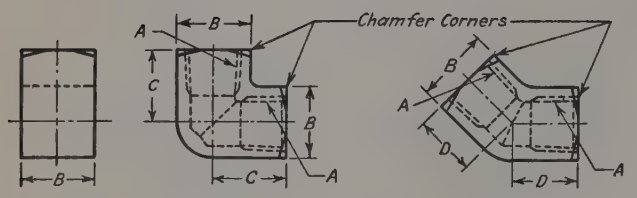


FIG. 11A FIG. 11B

FIG. 11—90-DEG AND 45-DEG PIPE ELBOWS

TABLE 6—*Dimensions of 90-Deg and 45-Deg Pipe Elbows (Fig. 11)*

DRYSEAL TAPER THREAD	BODY SIZE	CENTER TO END	
		90 deg	45 deg
A	*B*	*C*	*D*
1/16–27	7/16	1/2	7/16
1/8 –27	1/2	35/64	29/64
1/4 –18	11/16	25/32	21/32
3/8 –18	13/16	27/32	11/16
1/2 –14	1	1 3/32	29/32
3/4 –14	1 1/4	1 5/32	15/16
1 –11 1/2	1 1/2	1 33/64	1 3/16

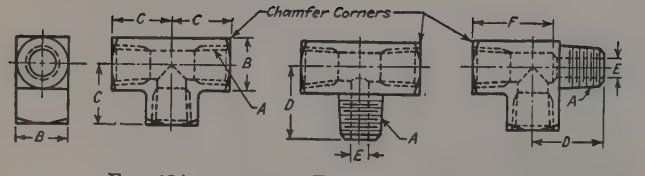


FIG. 12A FIG. 12B FIG. 12C

FIG. 12—TEES

TABLE 7—*Dimensions of Tees (Fig. 12)*

DRYSEAL TAPER THREAD	BODY SIZE	CENTER TO END		MAXIMUM HOLE DIAMETER	TAP-DRILL DEPTH
		Internal thread	External thread		
A	*B*	*C*	*D*	*E*	*F*
1/16–27	7/16	1/2	19/32	9/64	21/32
1/8 –27	1/2	35/64	5/8	7/32	3/4
1/4 –18	11/16	25/32	29/32	5/16	1 1/32
3/8 –18	13/16	27/32	31/32	7/16	1 11/64
1/2 –14	1	1 3/32	1 1/4	9/16	1 31/64
3/4 –14	1 1/4	1 5/32	1 3/8	3/4	1 21/32
1 –11 1/2	1 1/2	1 33/64	1 11/16	31/32	2 1/8

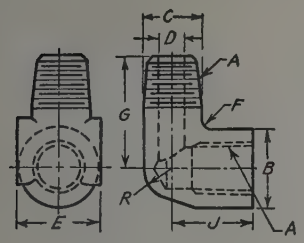
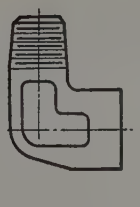


Fig. 13A



Pad Detail

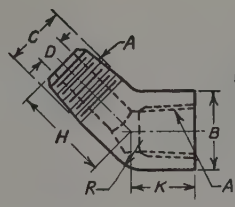
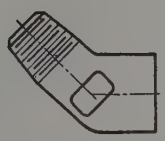


Fig. 13B



Pad Detail

FIG. 13—90-DEG AND 45-DEG STREET ELBOWS

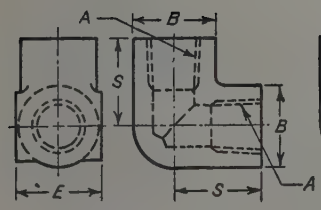
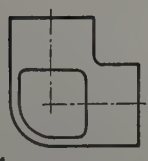


Fig. 14A



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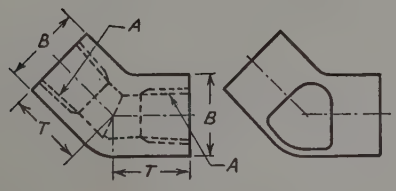
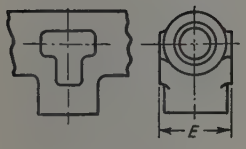


Fig. 14B

Pad Detail

FIG. 14—90-DEG AND 45-DEG PIPE ELBOWS



Pad Detail

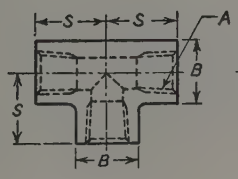


Fig. 15A

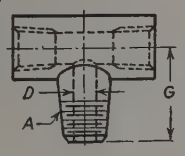


Fig. 15B

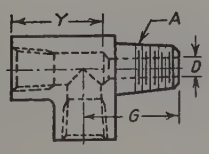


Fig. 15C

FIG. 15—TEES

TABLE 8—*Dimensions of 90-Deg and 45-Deg Street Elbows, Pipe Elbows, and Tees (Figs. 13A–15C)*

DRYSEAL TAPER THREAD	BODY DIAMETER	SHANK DIAMETER	MAXIMUM HOLE DIAMETER	ACROSS PAD	90- AND 45- DEG STREET ELBOWS AND TEES					90- AND 45-DEG PIPE ELBOWS AND TEES		
					Center to end				Radius	Center to end		Tap-drill depth, tees
					External thread		Internal thread					
					90 deg and tees	45 deg	90 deg	45 deg		90 deg and tees	45 deg	
A	*B*	*C*	*D*	*E*	*G*	*H*	*J*	*K*	*R*	*S*	*T*	*Y*
1/16 –27	—	—	—	—	—	—	—	—	—	—	—	—
1/8 –27	37/64	7/16	0.206	5/8	55/64	23/32	39/64	15/32	7/32	41/64	1/2	15/16
1/4 –18	25/32	37/64	0.283	13/16	1 7/32	1 3/64	57/64	5/8	9/32	57/64	11/16	1 9/64
3/8 –18	59/64	23/32	0.424	15/16	1 19/64	1 1/16	15/16	23/32	23/64	31/32	3/4	1 9/32
1/2 –14	1 5/32	57/64	0.518	1 3/16	1 39/64	1 11/32	1 11/64	29/32	7/16	1 15/64	15/16	1 5/8
3/4 –14	1 23/64	1 3/32	0.736	1 3/8	1 47/64	1 3/8	1 11/32	31/32	35/64	1 11/32	1	1 27/32
1 –11½	1 11/16	1 3/8	0.924	1 3/4	2 7/64	1 23/32	1 19/32	1 1/8	11/16	1 5/8	1 1/4	2 15/64

General Specifications

These specifications apply to all SAE automotive pipe fittings and, with respect to pipe threads, to parts with which fittings assemble.

Pipe Threads A—The pipe threads on pipe fittings, unless there is specific authorization to the contrary, shall conform with the Dryseal American (National) Standard Taper Pipe Thread (NPTF). At purchaser's option, the pipe thread on fittings may be shortened in conformity with the Dryseal SAE Short Taper Pipe Thread. Specifications for pipe threads are given in detail in the SAE Standard for Dryseal Pipe Threads.

Pipe-fitting dimensions in this Standard are based on the length of the Dryseal American (National) Standard Taper Pipe Thread (NPTF), because the consensus of manufacturer and user opinion is that trouble-free assembly and pressure-tight joints without lubricant or sealer cannot be assured unless a full-length thread is used.

Internal pipe threads shall be countersunk 90 deg inclusive to a diameter 0.01 in. above the major diameter.

External pipe threads shall be chamfered 45 deg to a diameter 0.01 in. below the minor diameter.

Related specifications covering blank sizes, blind-hole depths, pipe taps, chasers, drilled holes, and gages are shown in the SAE Standard for Dryseal Pipe Threads.

Internal Taper Pipe Threads—The tap-drill depths and the overall lengths specified in the preceding tables for automotive pipe fittings with internal taper pipe threads are not consistent with the tap-drill depths and the overall thread lengths of the Dryseal American (National) Standard Taper Pipe Threads (NPTF) specified in Table B2 of the SAE Standard Dryseal Pipe Threads. The full-length Dryseal American National Standard Taper Pipe Taps specified in Table B4 of the SAE Standard on Dryseal Pipe Threads cannot be used as the tap-drill depths and overall lengths of the fittings have been reduced to the minimum required by bottoming taps to produce standard full thread length. The deviations above described are peculiar to automotive pipe fittings. As special tooling is required, caution should be exercised in specifying the deviations for any other products.

Material and Manufacture—Pipe fittings may be made from cast iron, malleable iron, steel, brass, bronze, or aluminum alloy as indicated, unless otherwise specified by the purchaser, by casting, forging, or milling from the bar, or upsetting from a grade of material free from defects which will affect their serviceability.

Finish—If steel, cadmium or zinc plate; cadmium or zinc to a minimum thickness of 0.0002 in. and 32-hr. salt-spray test minimum.

Workmanship—Fittings shall be free of burrs, loose scale, sharp edges, eccentricity of diameters, and all other defects which affect their serviceability.

Dimensions and Tolerances—Dimensions apply to the finished parts, plated, hardened or otherwise processed, as specified by the purchaser. Tolerances on dimensions not otherwise limited shall be plus or minus 0.010 in. Minimum and maximum across-flat dimensions shall be commercial tolerances of bar or extruded material from which the parts are made.

Automotive Pipe Plugs

SAE Standard

Report of Parts and Fittings Technical Committee approved February 1948 and last revised by Tube, Pipe, Hose, and Lubrication Fittings Technical Committee April 1951.

Plugs for Cast Iron, Malleable Iron, and Steel

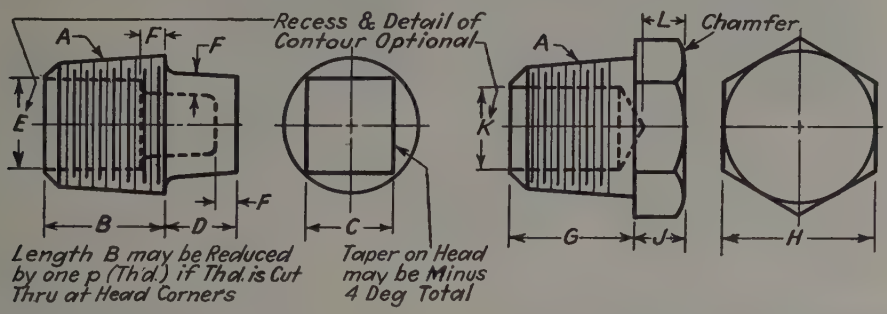


FIG. 1—SQUARE-HEAD PIPE PLUG

FIG. 2—HEXAGON-HEAD PIPE PLUG

TABLE 1—*Dimensions of Square-Head and Hexagon-Head Pipe Plugs (Figs. 1 and 2)*

DRYSEAL TAPER THREAD	SQUARE HEAD					HEXAGON HEAD				
	Body length	Square size	Head height	Maximum recess diameter	Minimum wall thickness	Shoulder length	Hex width	Hex thickness	Maximum recess diameter	Minimum wall thickness
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	*L*
1/16–27	0.330 0.350	0.214 0.221	0.178 0.193	—	—	0.37	0.304 0.315	0.151 0.162	—	—
1/8 –27	0.330 0.350	0.276 0.283	0.240 0.255	—	—	0.37	0.428 0.440	0.181 0.194	—	—
1/4 –18	0.495 0.525	0.370 0.377	0.280 0.300	—	—	0.56	0.551 0.565	0.181 0.194	—	—
3/8 –18	0.495 0.525	0.428 0.440	0.310 0.335	0.31	0.13	0.56	0.674 0.690	0.212 0.227	3/8	5/32
1/2 –14	0.660 0.700	0.553 0.565	0.380 0.410	0.38	0.16	0.75	0.860 0.877	0.212 0.227	1/2	5/32
3/4 –14	0.670 0.710	0.615 0.627	0.440 0.470	0.56	0.18	0.75	1.044 1.065	0.304 0.323	11/16	3/16
1 –11½	0.830 0.870	0.803 0.815	0.500 0.540	0.75	0.20	0.94	1.292 1.315	0.304 0.323	7/8	3/16

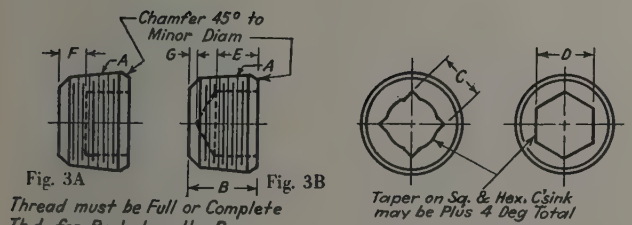


FIG. 3—(A) CAST OR MALLEABLE IRON AND (B) STEEL (BROACHED) PIPE PLUGS

Note—For Fig. 3B, slight rounding and broaching slugs left in broached hole are permissible

TABLE 2—*Dimensions of Square and Hexagon Countersunk Headless Pipe Plugs (Fig. 3)*

DRYSEAL TAPER THREAD	SQ AND HEX BODY LENGTH	SQUARE C'SUNK SIZE		HEX C'SUNK SIZE	MINIMUM SQ AND HEX SOCKET DEPTH	MINIMUM WALL THICKNESS	
		C				Cast or mall. iron	Steel
A	*B*	Cast	Broach	*D*	*E*	*F*	*G*
1/16–27	0.290 0.310	—	0.130 0.135	0.125 0.130	1/8	—	1/16
1/8 –27	0.290 0.310	—	0.192 0.197	0.188 0.193	1/8	—	1/16
1/4 –18	0.445 0.475	—	0.255 0.260	0.250 0.255	3/16	—	1/16
3/8 –18	0.445 0.475	0.319 0.349	0.319 0.324	0.313 0.318	3/16	0.13	1/16
1/2 –14	0.590 0.630	0.382 0.412	0.382 0.387	0.375 0.380	1/4	0.16	3/32
3/4 –14	0.600 0.640	0.413 0.443	0.413 0.418	0.563 0.568	5/16	0.18	3/32
1 –11½	0.750 0.790	0.508 0.538	0.508 0.513	0.625 0.630	3/8	0.20	1/8

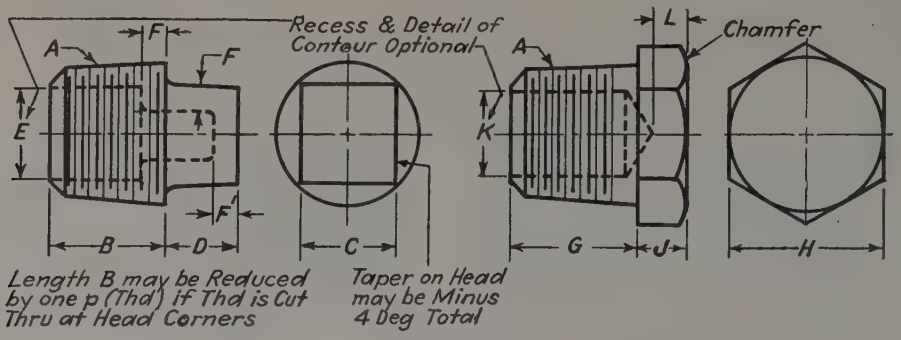


FIG. 4—SQUARE-HEAD PIPE PLUG

FIG. 5—HEXAGON-HEAD PIPE PLUG

TABLE 3—*Dimensions of Square-Head and Hexagon-Head Pipe Plugs (Figs. 4 and 5)*

DRYSEAL TAPER THREAD	SQUARE HEAD						HEXAGON HEAD				
	Body length	Square size	Head height	Maximum recess diameter	Minimum wall thickness		Shoulder length	Hex width	Hex thickness	Maximum recess diameter	Minimum wall thickness
A	*B*	*C*	*D*	*E*	*F*	*F'*	*G*	*H*	*J*	*K*	*L*
1/16–27	0.330 0.350	0.214 0.221	0.178 0.193	—	—	—	0.37	0.304 0.315	0.151 0.162	—	—
1/8 –27	0.330 0.350	0.276 0.283	0.240 0.255	—	—	—	0.37	0.428 0.440	0.181 0.194	—	—
1/4 –18	0.495 0.525	0.370 0.377	0.280 0.300	—	—	—	0.56	0.551 0.565	0.181 0.194	—	—
3/8 –18	0.495 0.525	0.428 0.440	0.310 0.335	0.36	0.11	0.08	0.56	0.674 0.690	0.212 0.227	3/8	5/32
1/2 –14	0.660 0.700	0.553 0.565	0.380 0.410	0.53	0.12	0.09	0.75	0.860 0.877	0.212 0.227	1/2	5/32
3/4 –14	0.670 0.710	0.615 0.627	0.440 0.470	0.72	0.13	0.10	0.75	1.044 1.065	0.304 0.323	11/16	3/16
1 –11½	0.830 0.870	0.803 0.815	0.500 0.540	0.93	0.14	0.11	0.94	1.292 1.315	0.304 0.323	7/8	3/16

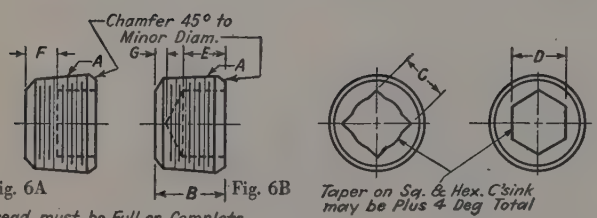


Fig. 6A Fig. 6B

FIG. 6—(A) CAST AND (B) BROACHED PIPE PLUGS

Note—For Fig. 6B slight rounding and broaching slugs left in broached hole are permissible

TABLE 4—*Dimensions of Square and Hexagon Countersunk Headless Pipe Plugs (Fig. 6)*

DRYSEAL TAPER THREAD	SQ AND HEX BODY LENGTH	SQUARE C'SUNK SIZE		HEX C'SUNK SIZE	MINIMUM SQ AND HEX SOCKET DEPTH	MINIMUM WALL THICKNESS	
						Cast	Broached
A	*B*	*C*		*D*	*E*	*F*	*G*
		Cast	Broach				
1/16–27	0.290 0.310	—	0.130 0.135	0.125 0.130	1/8	—	1/16
1/8 –27	0.290 0.310	—	0.192 0.197	0.188 0.193	1/8	—	1/16
1/4 –18	0.445 0.475	—	0.255 0.260	0.250 0.255	9/16	—	1/16
3/8 –18	0.445 0.475	0.319 0.349	0.319 0.324	0.313 0.318	3/16	0.08	1/16
1/2 –14	0.590 0.630	0.382 0.412	0.382 0.387	0.375 0.380	1/4	0.09	3/32
3/4 –14	0.600 0.640	0.413 0.443	0.413 0.418	0.563 0.568	5/16	0.10	3/32
1 –11½	0.750 0.790	0.508 0.538	0.508 0.513	0.625 0.630	3/8	0.11	1/8

General Specifications

These specifications apply to all SAE automotive pipe plugs and, with respect to pipe threads, to parts with which plugs assemble.

Pipe Threads—The pipe threads on pipe plugs, unless there is specific authorization to the contrary, shall conform with the Dryseal American (National) Standard Taper Pipe Thread (NPTF). Specifications for pipe threads are given in detail in the SAE Standard for Dryseal Pipe Threads.

Pipe-plug dimensions in this Standard are based on the length of the Dryseal American (National) Standard Taper Pipe Thread (NPTF), because the consensus of manufacturer and user opinion is that trouble-free assembly and pressure-tight joints without lubricant or sealer cannot be assured unless a full-length thread is used.

Shorter thread and body lengths are available in the pipe-threaded SAE Standard for Automotive Filler and Drain Plugs which have threads shortened in conformity with the Dryseal SAE Short Taper Pipe Thread (TF—SAE Short).

External pipe threads shall be chamfered 45 deg, or equivalent radius, to a diameter 0.01 in. below the minor diameter.

Related specifications covering blank sizes, dies, chasers, and gages are shown in the SAE Standard for Dryseal Pipe Threads.

Material and Manufacture—Pipe plugs may be made from cast iron, malleable iron, steel, brass, bronze, or aluminum alloy as indicated, unless otherwise specified by the purchaser, by casting, forging, or milling from the bar, or upsetting from a grade of material free from defects which will affect their serviceability.

Finish—If steel, cadmium or zinc plate; cadmium or zinc to a minimum thickness of 0.0002 in. and 32-hr salt spray test minimum.

Workmanship—Fittings shall be free of burrs, loose scale, sharp edges, eccentricity of diameters, and all other defects which affect their serviceability.

Dimensions and Tolerances—Dimensions apply to the finished parts, plated, hardened, or otherwise processed as specified by the purchaser. Tolerances on dimensions not otherwise limited shall be plus or minus 0.010 in.

A cross index of SAE designations for materials and parts appears after the last standard in this book.

Automotive Filler and Drain Plugs

SAE Standard

Report of Parts and Fittings Technical Committee approved February 1948 and last revised by Tube, Pipe, Hose, and Lubrication Fittings Technical Committee April 1951.

Types with Pipe Threads for Cast Iron, Malleable Iron, and Steel

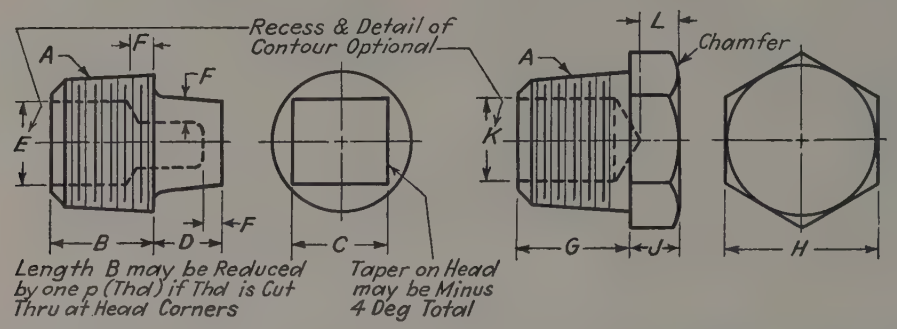


FIG. 1—SQUARE-HEAD DRAIN PLUG

FIG. 2—HEXAGON-HEAD DRAIN PLUG

TABLE 1—*Dimensions of Square-Head and Hexagon-Head Drain Plugs (Figs. 1 and 2)*

DRYSEAL TAPER THREAD, SAE SHORT	SQUARE HEAD					HEXAGON HEAD				
	Body length	Square size	Head height	Maximum recess diameter	Minimum wall thickness	Shoulder length	Hex width	Hex thickness	Maximum recess diameter	Minimum wall thickness
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	*L*
1/16–27	0.290 0.310	0.214 0.221	0.178 0.193	—	—	0.32	0.304 0.315	0.151 0.162	—	—
1/8 –27	0.290 0.310	0.276 0.283	0.240 0.255	—	—	0.32	0.428 0.440	0.181 0.194	—	—
1/4 –18	0.445 0.475	0.370 0.377	0.280 0.300	—	—	0.49	0.551 0.565	0.181 0.194	—	—
3/8 –18	0.445 0.475	0.428 0.440	0.310 0.335	0.31	0.13	0.49	0.674 0.690	0.212 0.227	3/8	5/32
1/2 –14	0.590 0.630	0.553 0.565	0.380 0.410	0.38	0.16	0.64	0.860 0.877	0.212 0.227	1/2	5/32
3/4 –14	0.600 0.640	0.615 0.627	0.440 0.470	0.56	0.18	0.65	1.044 1.065	0.304 0.323	11/16	3/16
1 –11½	0.750 0.790	0.803 0.815	0.500 0.540	0.75	0.20	0.81	1.292 1.315	0.304 0.323	7/8	3/16

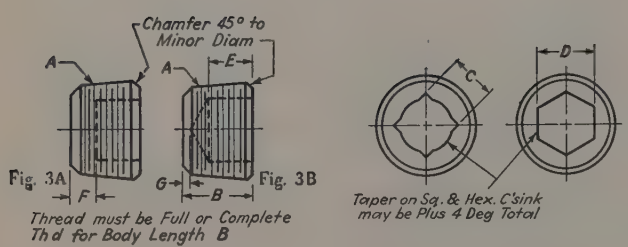


FIG. 3—(A) CAST OR MALLEABLE IRON AND (B) STEEL (BROACHED) DRAIN PLUGS

Note—For Fig. 3B, slight rounding and broaching slugs left in broached hole are permissible

TABLE 2—*Dimensions of Square and Hexagon Countersunk Headless Drain Plugs (Fig. 3)*

DRYSEAL TAPER THREAD, SAE SHORT	SQ AND HEX BODY LENGTH	SQUARE C' SUNK SIZE		HEX C'SUNK SIZE	MINIMUM SQ AND HEX SOCKET DEPTH	MINIMUM WALL THICKNESS	
						CAST OR MALL. IRON	STEEL
A	*B*	*C*		*D*	*E*	*F*	*G*
		Cast	Broach				
1/16–27	0.250 0.270	—	0.130 0.135	0.125 0.130	3/32	—	1/16
1/8 –27	0.260 0.280	—	0.192 0.197	0.188 0.193	3/32	—	1/16
1/4 –18	0.395 0.425	—	0.255 0.260	0.250 0.255	5/32	—	1/16
3/8 –18	0.395 0.425	0.319 0.349	0.319 0.324	0.313 0.318	5/32	0.13	1/16
1/2 –14	0.520 0.560	0.382 0.412	0.382 0.387	0.375 0.380	3/16	0.16	3/32
3/4 –14	0.530 0.570	0.413 0.443	0.413 0.418	0.563 0.568	3/16	0.18	3/32
1 –11½	0.670 0.710	0.508 0.538	0.508 0.513	0.625 0.630	1/4	0.20	1/8

Types with Pipe Threads for Brass, Bronze, and Aluminum Alloys

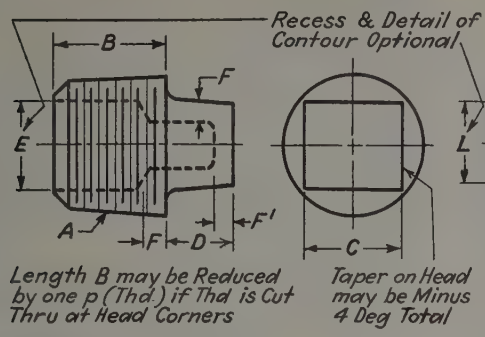


FIG. 4—SQUARE-HEAD DRAIN PLUG

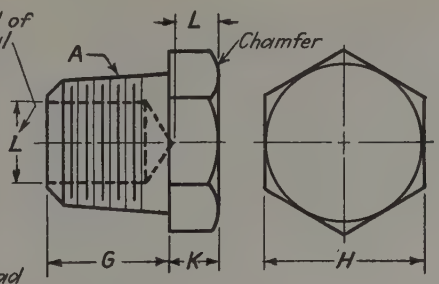


FIG. 5—HEXAGON-HEAD DRAIN PLUG

TABLE 3—*Dimensions of Square-Head and Hexagon-Head Drain Plugs (Figs. 4 and 5)*

DRYSEAL TAPER THREAD, SAE SHORT	SQUARE HEAD						HEXAGON HEAD				
	Body length	Square size	Head height	Maximum recess diameter	Minimum wall thickness		Shoulder length	Hex width	Hex thickness	Maximum recess diameter	Minimum wall thickness
A	*B*	*C*	*D*	*E*	*F*	*F'*	*G*	*H*	*J*	*K*	*L*
1/16–27	0.290 0.310	0.214 0.221	0.178 0.193	—	—	—	0.32	0.304 0.315	0.151 0.162	—	—
1/8 –27	0.290 0.310	0.276 0.283	0.240 0.255	—	—	—	0.32	0.428 0.440	0.181 0.194	—	—
1/4 –18	0.445 0.475	0.370 0.377	0.280 0.300	—	—	—	0.49	0.551 0.565	0.181 0.194	—	—
3/8 –18	0.445 0.475	0.428 0.440	0.310 0.335	0.36	0.11	0.08	0.49	0.674 0.690	0.212 0.227	3/8	5/32
1/2 –14	0.590 0.630	0.553 0.565	0.380 0.410	0.53	0.12	0.09	0.64	0.860 0.877	0.212 0.227	1/2	5/32
3/4 –14	0.600 0.640	0.615 0.627	0.440 0.470	0.72	0.13	0.10	0.65	1.044 1.065	0.304 0.323	11/16	3/16
1 –11½	0.750 0.790	0.803 0.815	0.500 0.540	0.93	0.14	0.11	0.81	1.292 1.315	0.304 0.323	7/8	13/16

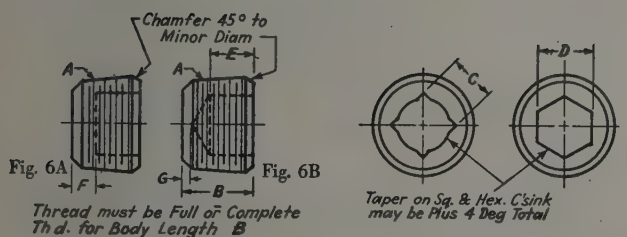


FIG. 6—(A) CAST AND (B) BROACHED DRAIN PLUGS

Note—For Fig. 6B, slight rounding and broaching slugs left in broached hole are permissible

TABLE 4—*Dimensions of Square and Hexagon Countersunk Headless Drain Plugs (Fig. 6)*

DRYSEAL TAPER THD, SAE SHORT	SQ AND HEX BODY LENGTH	SQUARE C'SUNK SIZE		HEX C'SUNK SIZE	MINIMUM SQ AND HEX SOCKET DEPTH	MINIMUM WALL THICKNESS	
		C				Cast	Broached
A	*B*	Cast	Broach	*D*	*E*	*F*	*G*
1/16–27	0.250 0.270	—	0.130 0.135	0.125 0.130	3/32	—	1/16
1/8 –27	0.260 0.280	—	0.192 0.197	0.188 0.193	3/32	—	1/16
1/4 –18	0.395 0.425	—	0.255 0.260	0.250 0.255	5/32	—	1/16
3/8 –18	0.395 0.425	0.319 0.349	0.319 0.324	0.313 0.318	5/32	0.08	1/16
1/2 –14	0.520 0.560	0.382 0.412	0.382 0.387	0.375 0.380	3/16	0.09	3/32
3/4 –14	0.530 0.570	0.413 0.443	0.413 0.418	0.563 0.568	3/16	0.10	3/32
1 –11½	0.670 0.710	0.508 0.538	0.508 0.513	0.625 0.630	1/4	0.11	1/8

General Specifications

These specifications apply to all SAE automotive filler and drain plugs with taper pipe threads and, with respect to pipe threads, to parts with which plugs assemble.

Pipe Threads—The pipe threads on filler and drain plugs, unless there is specific authorization to the contrary, shall conform with the Dryseal SAE Short Taper Pipe Thread (PTF—SAE Short). Specifications for pipe threads are given in detail in the SAE Standard for Dryseal Pipe Threads.

Filler and drain-plug dimensions in this Standard are based on the length of the Dryseal SAE Short Taper Pipe Thread (PTF—SAE Short). Limitations on the use of this thread are explained in the SAE Standard for Dryseal Pipe Threads.

Longer thread and body lengths are available in the automotive pipe plugs which have threads in conformity with the Dryseal American (National) Standard Taper Pipe Thread (NPTF).

External pipe threads shall be chamfered 45 deg, or equivalent radius, to a diameter 0.01 in. below the minor diameter.

Related specifications covering blank sizes, dies, chasers, and gages are shown in the SAE Standard for Dryseal Pipe Threads.

Material and Manufacture—Pipe plugs may be made from cast iron, malleable iron, steel, brass, bronze, or aluminum alloy as indicated, unless otherwise specified by the purchaser, by casting, forging, or milling from the bar, or upsetting from a grade of material free from defects which will affect their serviceability.

Finish—If steel, cadmium or zinc plate; cadmium or zinc to a minimum thickness of 0.0002 in. and 32-hr salt-spray test minimum.

Workmanship—Fittings shall be free of burrs, loose scale, sharp edges, eccentricity of diameters, and all other defects which affect their serviceability.

Dimensions and Tolerances—Dimensions apply to the finished parts, plated, hardened or otherwise processed, as specified by the purchaser. Tolerances on dimensions not otherwise limited shall be plus or minus 0.010 in.

General Specifications

These specifications apply to all SAE automotive filler and drain plugs with straight threads and, with respect to straight threads, to parts with which plugs assemble.

Straight Threads A_1—Unified and American Standard Class 2A external thread shall be used for straight-threaded drain plugs. Class 2B internal thread shall be used for parts with which plugs assemble. The pitch-diameter tolerance shall be the same as the corresponding diameter-pitch combination and class of the Unified Coarse- and Fine-Thread Series. Special diameter-pitch combinations shall be based on diameter, pitch, and length of engagement of 9× pitch.

External threads shall be chamfered 45 deg to a diameter 0.01 in. below the minor diameter.

Material and Manufacture—Filler and drain plugs may be made from cast iron, malleable iron, steel, brass, bronze, or aluminum alloy as indicated, unless otherwise specified by the purchaser, by casting, forging, or milling from the bar, or upsetting from a grade of material free from defects which will affect their serviceability.

Finish—If steel, cadmium or zinc plate; cadmium or zinc to a minimum thickness of 0.0002 in. and 32-hr salt-spray test minimum.

Workmanship—Parts shall be free from burrs, loose scale, sharp edges, eccentricity of diameters, and all other defects which affect their serviceability.

Dimensions and Tolerances—Dimensions apply to the finished parts, plated, hardened or otherwise processed, as specified by the purchaser. Tolerances on dimensions not otherwise limited shall be plus or minus 0.010 in. The washer face diameter shall be 95% of maximum width across flats with a tolerance of plus or minus 5%.

Types with Straight Threads

The dimensions of the first figure in each group apply to all other figures in that group except as shown otherwise.

For broached holes, slight rounding and broaching slugs left in broached holes are permissible.

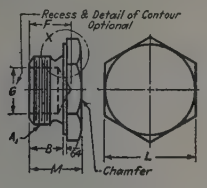


Fig. 7—Hexagon Outside Head Drain Plug

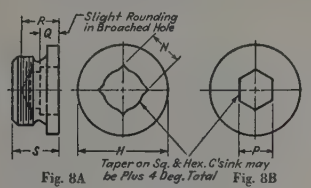


Fig. 8A Fig. 8B

Fig. 8—Square and Hexagon Countersunk Filler and Drain Plugs

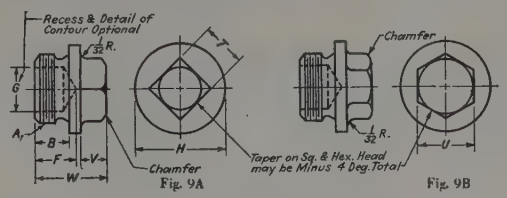


Fig. 9A Fig. 9B

Fig. 9—Square and Hexagon Inside Head Filler and Drain Plugs

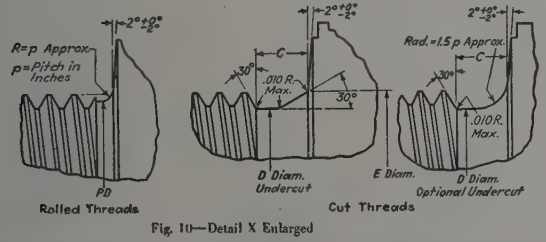
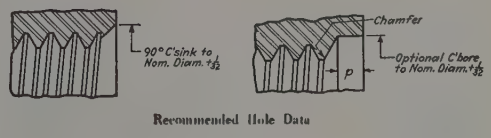


Fig. 10—Detail X Enlarged



Recommended Hole Data

TABLE 5—*Dimensions of Hexagon Outside Head, Square and Hexagon Countersunk, and Square and Hexagon Inside Head Filler and Drain Plugs (Figs. 7–10)*

STRAIGHT THREAD	SHOULDER LENGTH	RELIEF WIDTH	RELIEF DIAMETER	PILOT DIAMETER	RECESS DRILL-POINT DEPTH	MAXIMUM RECESS DRILL DIAMETER	FLANGE DIAMETER	HEX OUTSIDE HEAD		SQUARE AND HEXAGON COUNTERSUNK					SQUARE AND HEXAGON INSIDE HEAD			
								Hex width	Overall length	Sq size	Hex size	Min socket depth	Drill-point depth	Overall length	Sq size	Hex size	Sq and hex height	Overall length
A_1	B	C	D	E	F	G	H	L	M	N	P	Q	R	S	T	U	V	W
5/16–24	5/16	3/32	0.252 0.245	0.328 0.321	—	—	9/16	0.565 0.551	1/2	0.130 0.135	0.156 0.161	1/8	5/16	7/16	0.221 0.214	0.283 0.276	7/32	21/32
3/8–24	5/16	3/32	0.314 0.307	0.391 0.384	—	—	5/8	0.627 0.612	1/2	0.192 0.197	0.188 0.193	1/8	5/16	7/16	0.283 0.276	0.315 0.304	1/4	11/16
1/2–20	11/32	3/32	0.428 0.421	0.516 0.509	13/32	1/4	3/4	0.752 0.737	17/32	0.255 0.260	0.250 0.255	3/16	11/32	15/32	0.377 0.370	0.440 0.428	1/4	23/32
5/8–18	3/8	1/8	0.545 0.537	0.641 0.633	15/32	3/8	7/8	0.877 0.860	5/8	0.319 0.324	0.313 0.318	3/16	3/8	1/2	0.440 0.428	0.502 0.489	9/32	25/32
3/4–16	3/8	1/8	0.660 0.651	0.766 0.757	15/32	1/2	1	1.002 0.983	5/8	0.382 0.387	0.375 0.380	1/4	13/32	17/32	0.502 0.490	0.565 0.551	9/32	13/16
7/8–18	13/32	1/8	0.793 0.785	0.891 0.883	1/2	9/16	1 1/8	1.127 1.106	21/32	0.413 0.418	0.500 0.505	1/4	7/16	9/16	0.565 0.553	0.627 0.612	5/16	7/8
1 –18	7/16	1/8	0.918 0.910	1.016 1.008	9/16	11/16	1 1/4	1.252 1.230	3/4	0.413 0.418	0.563 0.568	1/4	15/32	19/32	0.627 0.615	0.815 0.798	5/16	29/32
1 1/4–18	15/32	1/8	1.167 1.159	1.266 1.258	19/32	15/16	1 1/2	1.502 1.477	25/32	0.508 0.513	0.625 0.630	5/16	17/32	21/32	0.815 0.803	1.002 0.983	11/32	1
1 1/2–18	1/2	1/8	1.417 1.409	1.516 1.508	11/16	1 1/8	1 3/4	1.752 1.725	7/8	0.632 0.637	0.750 0.755	3/8	5/8	3/4	0.940 0.928	1.127 1.106	3/8	1 1/8
1 3/4–16	9/16	1/8	1.657 1.648	1.766 1.757	3/4	1 3/8	2	2.002 1.974	15/16	0.759 0.764	0.875 0.880	3/8	11/16	13/16	1.127 1.115	1.252 1.230	7/16	1 1/4
2 –16	9/16	1/8	1.907 1.898	2.016 2.007	3/4	1 5/8	2 1/4	2.252 2.232	15/16	0.884 0.889	1.125 1.130	3/8	3/4	7/8	1.315 1.302	1.502 1.477	7/16	1 5/16

TABLE 6—*Dimensions of Hexagon Outside Head, Square and Hexagon Countersunk, and Square and Hexagon Inside Head Filler and Drain Plugs (Figs. 7–10)*

STRAIGHT THREAD, MM	SHOULDER LENGTH	RELIEF WIDTH	RELIEF DIAMETER	PILOT DIAMETER	RECESS DRILL-POINT DEPTH	MAXIMUM RECESS-DRILL DIAMETER	FLANGE DIAMETER	HEX OUTSIDE HEAD		SQUARE AND HEXAGON COUNTERSUNK					SQUARE AND HEXAGON INSIDE HEAD			
								Hex width	Overall length	Sq size	Hex size	Min socket depth	Drill-point depth	Overall length	Sq size	Hex size	Sq and hex height	Overall length
A_1	B	C	D	E	F	G	H	L	M (for ref)	N	P	Q	R	S (for ref)	T	U	V	W (for ref)
10 x 1	5/16	3/32	0.336 0.329	0.410 0.403	—	—	5/8	0.627 0.612	1/2	0.192 0.197	0.188 0.193	1/8	5/16	7/16	0.283 0.276	0.315 0.304	1/4	11/16
14 x 1.25	11/32	3/32	0.480 0.473	0.567 0.560	13/32	5/16	13/16	0.814 0.799	17/32	0.255 0.260	0.250 0.255	3/16	11/32	15/32	0.377 0.370	0.440 0.428	1/4	23/32
18 x 1.5	3/8	1/8	0.623 0.614	0.724 0.715	15/32	7/16	15/16	0.940 0.921	5/8	0.382 0.387	0.375 0.380	1/4	13/32	17/32	0.502 0.490	0.565 0.551	9/32	13/16

Lubrication Fittings

SAE Standard

Report of Parts and Fittings Technical Committee approved January 1949 and last revised by Tube, Pipe, Hose, and Lubrication Fittings Technical Committee April 1951.

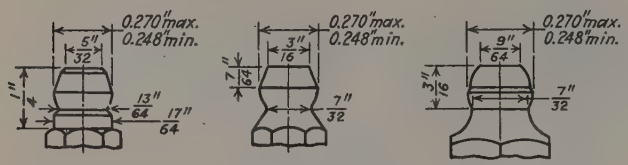


FIG. 1A FIG. 1B FIG. 1C

FIG. 1—OPTIONAL TIPS FOR LUBRICATION FITTINGS

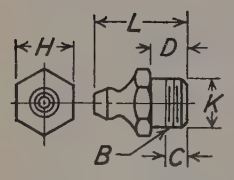


FIG. 2A—EXTERNAL THREAD

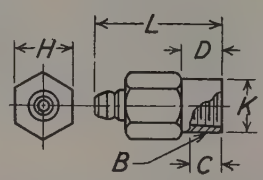


FIG. 2B—INTERNAL THREAD

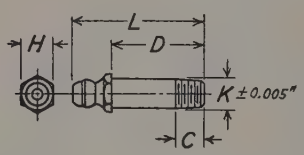


FIG. 2C—¼-28 TAPER THREAD

FIG. 2—STRAIGHT HYDRAULIC FITTINGS

TABLE 1—*Dimensions of Straight Hydraulic Fittings (Fig. 2)*

TYPES	TAPER PIPE THREAD, B	TAPER THREAD, B	EFFECTIVE THREAD LENGTH, C	SHANK LENGTH, APPROX D	HEX SIZE, H	SHANK DIAM, K	OVERALL LENGTH, APPROX L
Fig. 2A, external thread	⅛ [a]	—	3/16	9/32	7/16	0.400	21/32
	⅛ [a]	—	3/16	9/32	7/16	0.400	¾
	⅛ [a]	—	3/16	¾	7/16	0.400	1¼
	⅛ [b]	—	¼	19/32	7/16	0.400	1¾
	⅛ [c]	—	5/16	25/32	7/16	0.400	2⅝
	¼ [a]	—	9/32	11/32	9/16	0.530	15/16
Fig. 2B, internal thread	⅛ [b]	—	¼	5/16	½	31/64	1 3/32
Fig. 2C, taper thread	—	¼-28	7/64	3/16	9/32 or 5/16	0.252	½
	—	¼-28	15/64	11/32	9/32 or 5/16	0.260	11/16
	—	¼-28	15/64	⅝	9/32 or 5/16	0.260	15/16
	—	¼-28	15/64	13/16	17/64	0.260	1⅛

[a] PTF Special Extra Short.
[b] PTF Special Short.
[c] NPTF.

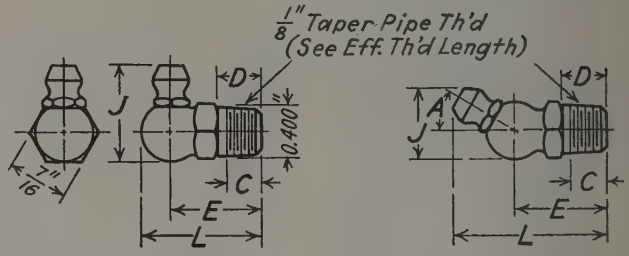


FIG. 3A—⅛ TAPER PIPE THREAD FIG. 3B—⅛ TAPER PIPE THREAD

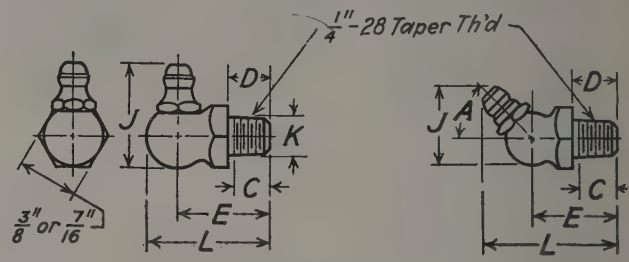


FIG. 3C—¼-28 TAPER THREAD FIG. 3D—¼-28 TAPER THREAD

FIG. 3—ANGLE HYDRAULIC FITTINGS

TABLE 2—*Dimensions of Angle Hydraulic Fittings (Fig. 3)*

TYPES	ANGLE A, DEG	EFFECTIVE THREAD LENGTH, C	APPROXIMATE SHANK LENGTH, D	APPROXIMATE END TO CENTER, E	APPROXIMATE OVERALL HEIGHT, J	APPROXIMATE OVERALL LENGTH, L	SHANK DIAM, K
Figs. 3A and 3B, ⅛ taper pipe thread	30	3/16 [a]	9/32	⅝	9/16	1 3/32	—
	30	5/16 [b]	1¼	1⅝	9/16	2 3/32	—
	60–67½	3/16 [a]	9/32	⅝	23/32	29/32	—
	60–67½	5/16 [b]	9/16	29/32	23/32	1 3/16	—
	85–90	3/16 [a]	9/32	⅝	¾	⅞	—
	85–90	5/16 [b]	1¼	1⅝	¾	1⅞	—
Figs. 3C and 3D, ¼-28 taper thread	45	7/64	3/16	15/32	19/32	⅞	0.252
	45	15/64	11/32	19/32	19/32	31/32	0.260
	85–90	7/64	3/16	9/16	1 1/16	¾	0.252

[a] PTF Special Extra Short.
[b] NPTF.

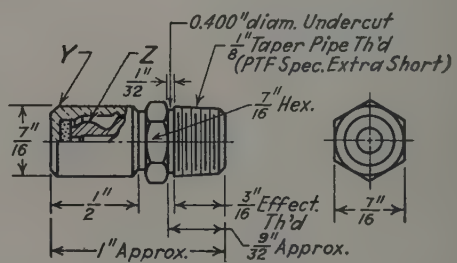


FIG. 4—WATER-PUMP TYPE

Body—steel, cadmium plated
Cap, Y—brass or aluminum without plating
Tip, Z—steel, cadmium plated

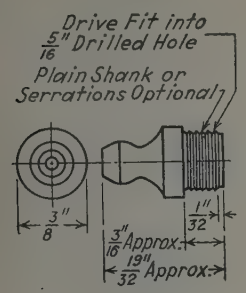


FIG. 5A

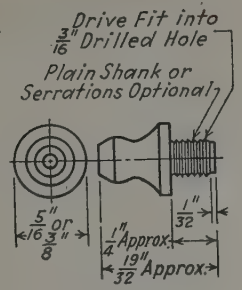


FIG. 5B

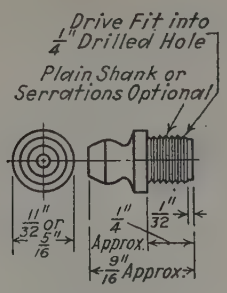


FIG. 5C

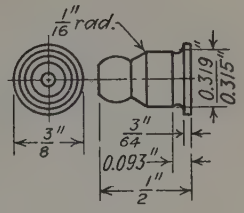


FIG. 5D

FIG. 5—HYDRAULIC STRAIGHT DRIVE BASE TYPES

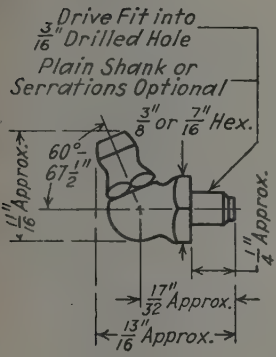


FIG. 6A

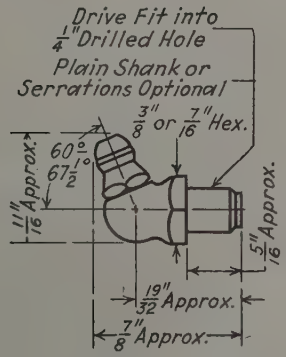


FIG. 6B

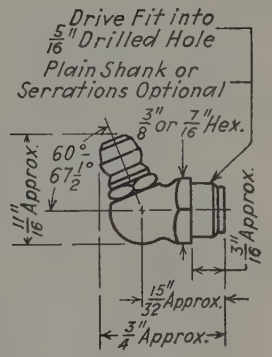


FIG. 6C

FIG. 6—ELBOWS, DRIVE BASE TYPES

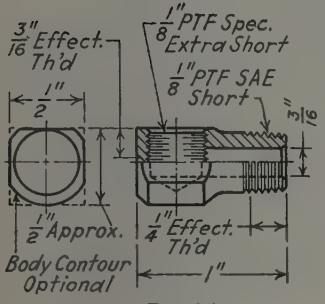


FIG. 7A

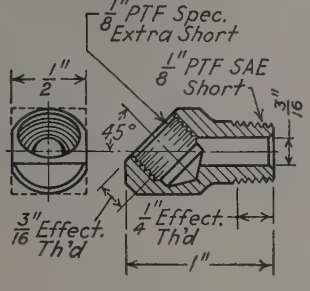


FIG. 7B

FIG. 7—ELBOW ADAPTERS

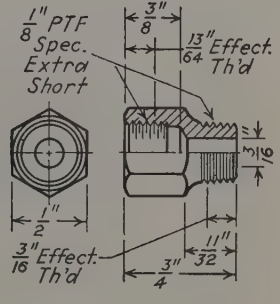


FIG. 8—EXTENSION

General Specifications

These specifications apply to all SAE lubrication fittings and, with respect to pipe threads, to parts into which fittings assemble.

Pipe Threads—The pipe threads, unless there is specific authorization to the contrary, shall conform with Dryseal American (National) Standard Taper Pipe Threads except for varying lengths of thread, related gaging tolerance, and form of crest. Experience has shown that the crest of the threads on lubrication fittings, intended for use with grease, does not have to conform to Dryseal American (National) Standard Form to function satisfactorily. The thread crests may have greater maximum truncation due to manufacturing practices. These deviations are not advisable in any other application of pipe-thread practice. Specifications for pipe threads are given in detail in the SAE Standard for Dryseal Pipe Threads.

External pipe threads shall be chamfered 45 deg to a diameter 0.01 in. below the minor diameter.

Internal pipe threads shall be countersunk 90 deg inclusive to a diameter 0.01 in. above the major diameter.

Related specifications covering blank sizes, blind-hole depths, pipe taps, chasers, drilled holes, and gages are shown in the SAE Standard for Dryseal Pipe Threads.

External Taper Pipe Threads—The shoulder lengths and the full thread lengths specified in the preceding tables for lubrication fittings with external taper pipe threads are not consistent with the shoulder lengths and the full thread lengths of the Dryseal American (National) Standard Taper Pipe Thread (NPTF)

specified in Table 2 and Table B1 of the SAE Standard for Dryseal Pipe Threads. The full thread lengths specified in Table 2 of the SAE Standard for Dryseal Pipe Threads cannot be used as the shoulder lengths have been reduced to the minimum required for economy of manufacture or for customer needs. The deviations above described are peculiar to lubrication fittings. As special considerations are involved, caution should be exercised in specifying the deviations for any other products.

External-Pipe-Thread Terminology—Dryseal American (National) External Taper Pipe Thread (NPTF) is standard full thread length with gaging tolerance as specified in Table 2 and Appendix A of the SAE Standard for Dryseal Pipe Threads. Dryseal SAE Short External Taper Pipe Thread (PTF—SAE Short) is shortened one thread at the small end with gaging tolerance as specified in Table 3 and Appendix A of the SAE Standard for Dryseal Pipe Threads.

Dryseal Special Short External Taper Pipe Thread (PTF—Spl Short) is shortened one thread at the small end and also one thread at the large end and is gaged the same as SAE Short, using thin-ring gage only.

Dryseal Special Extra Short External Taper Pipe Thread (PTF—Spl Extra Short) is shortened one thread at the small end and also two threads at the large end and is gaged 1¾ to 3¼ turns engagement for ⅛-in. size using special thin-ring gage with one-half pitch (thread) ground off large end and rechamfered.

Internal Taper Pipe Threads—The tap-drill depths and the full thread lengths specified in the preceding tables for lubrication fittings with internal taper pipe threads are not consistent with the tap-drill depths and the full thread lengths of the Dryseal American (National) Standard Taper Pipe Thread (NPTF) specified in Table B2 of the SAE Standard for Dryseal Pipe Threads. The full-length Dryseal American National Standard Taper Pipe Taps specified in Table B4 of the SAE Standard for Dryseal Pipe Threads cannot be used as the tap-drill depths and full thread lengths have been reduced to the minimum required by short bottoming taps for economy of manufacture or for customer needs. The deviations above described are peculiar to lubrication fittings. As special tooling and other considerations are required, caution should be exercised in specifying the deviations for any other products.

Internal-Pipe-Thread Terminology—Dryseal American (National) Internal Taper Pipe Thread (NPTF) is standard full thread length with gaging tolerance as specified in Table 2 and Appendix A of SAE Standard for Dryseal Pipe Threads. When used with lubrication fittings which have external thread with shorter length of full thread than SAE Short, the internal thread should be held closer than standard tolerance toward the minimum PD.

Dryseal SAE Short Internal Taper Pipe Thread (PTF—SAE Short) is shortened one thread at the large end with gaging tolerance as specified in Table 4 and Appendix A of SAE Standard for Dryseal Pipe Threads. When used with lubrication fittings which have external thread at small end gaged similar to SAE Short, the internal thread or the external thread or both should be held closer than standard tolerance, the internal thread toward the maximum PD and the external thread toward the minimum PD, to provide a minimum of one turn hand engagement.

Dryseal Special Short Internal Taper Pipe Thread (PTF—Spl Short) is shortened one thread at the large end and also one thread at the small end and is gaged the same as SAE Short.

Dryseal Special Extra Short Internal Taper Pipe Thread (PTF—Spl Extra Short) is shortened one thread at the large end and also two threads at the small end and is gaged the same as SAE Short.

Straight Internal Pipe Threads—Straight internal pipe threads for assembly with external taper pipe thread on lubrication fittings should be tapped with Dryseal (National) Fuel Straight Pipe Taps (NPSF). This tap, having been adjusted on ⅛- and ¼-in. sizes to obtain threads for hand engagement and wrench take-up proportionate to all other sizes, supersedes the American Grease Fitting Tap. When used with lubrication fittings which have external thread at small end gaged similar to SAE Short, the internal-thread gaging should be held closer than standard tolerance, toward the maximum PD, to provide a minimum of one turn hand engagement.

¼-28 Taper Threads (SAE—LT)—External taper thread shall be Unified and American Standard Thread ¼-28 with ¾ taper on diameter per foot, PD 0.2257 plus zero, minus 0.0033 in., tolerance measured at start of thread at small end. Straight internal thread for assembly with external taper thread on lubrication fittings should be tapped with ¼-28 UNF straight thread, Class 3B pitch-diameter tolerance, and 75% minimum thread height.

Straight Threads (External and Internal)—Unified and American Standard Class 2A external and Class 2B internal threads shall be used.

External threads shall be chamfered 45 deg to a diameter 0.01 in. below the minor diameter.

Internal threads shall be countersunk 90 deg inclusive to a diameter 0.01 in. above the major diameter.

Thread-Length Definitions—Full or perfect thread length is the distance from the start of the thread to the last thread which is perfect at crest and root.

Effective thread length includes the full or perfect threads plus the threads perfect at the root but imperfect at the crest, such as obtained on standard OD pipe and with commercial drill sizes.

Total thread length includes the effective thread length plus thread run out from die or chaser for external threads or imperfect threads from tap chamfer for internal threads.

Material and Manufacture—Fittings shall be brass or steel unless otherwise specified on drawing or by the purchaser. The greasing end of steel fittings shall be cyanided or otherwise hardened sufficiently to resist scoring by guns or couplers and damage from stones.

Service—All fitting-tip dimensions and contours shall be optional except that the design shall be such that fittings are readily serviced with conventional standard hydraulic-grip-type couplers in the field.

Finish—If steel, cadmium or zinc plate; cadmium or zinc thickness of 0.0002 in. minimum and 32-hr salt-spray test minimum.

Dimensions and Tolerance—Dimensions apply to finished parts, plated, hardened, or otherwise processed, as specified by purchaser. Tolerances on dimensions not otherwise limited shall be plus or minus $\frac{1}{64}$ in. Dimensions marked "approx" shall be limited to plus $\frac{1}{16}$, minus ¼ in. Bar-stock tolerances are commercial.

Defects—Fittings shall be free from burrs, loose scale, sharp edges, eccentricity of diameters, and all other defects which affect their serviceability.

Check Valve—All standard lubrication fittings are furnished with check valve. Special fittings without valve are not recommended by the lubrication industry.

Drain Cocks

SAE Recommended Practice

Report of Screw Threads Division approved July 1921.

TABLE 1—*Drain-Cock Dimensions*

THREAD SIZE[a]	EQUIVALENT PASSAGE DIAMETER, MINIMUM[b]	THREAD SIZE[a]	EQUIVALENT PASSAGE DIAMETER, MINIMUM[b]
1/8	5/32	3/8	11/32
1/4	1/4	1/2	7/16

[a] Taper pipe thread.
[b] The cross-sectional area of the passages throughout their lengths shall be not less than those obtained with the minimum diameters given.

Water-Pipe Flanges

SAE Recommended Practice

Report of Parts and Fittings Division approved March 1922 and last revised by Radiator Division July 1926.

TABLE 1—*Dimensions of Water-Pipe Flanges*

NOMINAL FLANGE SIZE, IN.	1 3/16	1 7/16	1 11/16	1 15/16	2 3/16
Outside diameter, *K*, in.	1 1/2	1 3/4	2	2 1/4	2 1/2
Inside diameter, *A*, in.	1 3/16	1 7/16	1 11/16	1 15/16	2 3/16
B	1 3/16	1 11/32	1 15/32	1 21/32	1 25/32
C	1 7/8	2 3/16	2 1/2	2 13/16	3 1/8
D	11/32	13/32	13/32	15/32	15/32
E	11/32	13/32	13/32	15/32	15/32
F	13/32	15/32	15/32	9/16	9/16
G	7/32	1/4	1/4	9/32	9/32
Length,[a] in., min	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2
J	5/32	5/32	5/32	5/32	5/32
Capscrews, NC—2	5/16–18	3/8–16	3/8–16	7/16–14	7/16–14

[a] Length of fitting for lap of hose.

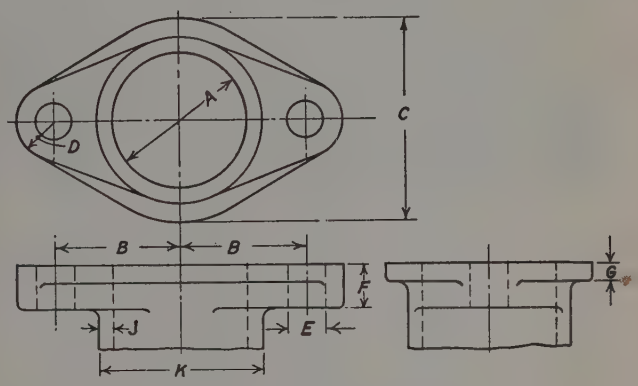


FIG. 1—WATER-PIPE FLANGE

Pressure-Gage Connections

SAE Recommended Practice

Report of Screw Threads Division approved March 1922.

TABLE 1—*Dimensions of Pressure-Gage Connections*

TUBING DIAMETER	*B*, NF—2	*C*, MINIMUM	*D*, MINIMUM USABLE THREAD
1/4	7/16–20	1/2	11/32
5/16	1/2–20	9/16	3/8
3/8	5/8–18	5/8	13/32

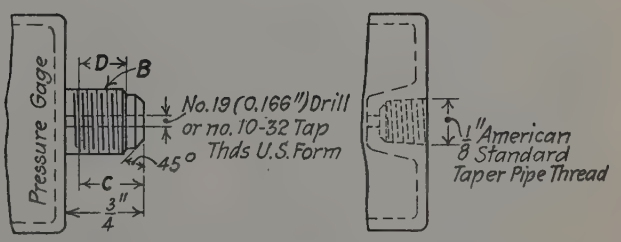


FIG. 1—PRESSURE-GAGE CONNECTIONS

Note—Connection shown at right is intended for pressure gages where type of construction shown at left is not applicable

Automobile Wiring

SAE Recommended Practice

Report of Electrical Equipment Division approved January 1932 and last revised January 1945.

[*Economy, operating safety, efficiency, and accessibility are the basis for this SAE Recommended Practice for wiring.*]

Definitions—The systems of installation commonly known as two wire or single wire shall be termed respectively "insulated-return" and "ground-return" systems. Installations in which the chassis frame is used as part of the return circuit shall be considered as ground-return systems.

Insulated Cable—All insulated cable should conform to the SAE Standard for Insulated Cable. Terminals on other than starting-motor cables should be clamped to the insulation and soldered or welded to the conductors. The use of crimped terminals shall be restricted to applications in the lighting circuits. SAE Standard terminals or lugs should be used on starting-motor cables. Conductor cross-sections should be such that the potential loss at normal load will not exceed 10%.

The insulated cables comprising the automobile wiring circuits should, where possible, be grouped together and protected by nonmetallic tape or braid covering capable of withstanding severe abrasion except where otherwise protected or not in contact with metal surfaces. This wiring assembly should be cleated at intervals so as to be properly supported, and it should be located so that no portion is closer than 1 in. to the carburetor, gasoline line, and moving parts and at least 2 in. from the exhaust pipe. The edges of all holes in metal members through which the cable passes should be rolled or bushed with rubber grommets. For extra protection, double or triple tape or braid covering should be supplied.

Grounding—Wherever a conductor is connected to ground, it should be accessible for repair. Ground-return connections should be made to the chassis frame or engine. In cases where the engine or body is mounted on rubber or other insulation, proper ground should be provided. The surface on which the terminals make contact should be clean and free from oxide or paint.

Battery Installation—The storage-battery compartment or metal parts near the storage battery should be painted with an acid-resisting paint and should have openings to provide ample battery ventilation and drainage. At the point where the live line passes through a metal compartment, the cable should be protected against grounding by an acid-proof and waterproof insulated bushing. Where a battery and a gasoline tank are both placed under the driver's seat, they should be partitioned from each other and each compartment should be provided with an independent cover, ventilation, and drainage.

Overload Protective Devices—The current to all low-tension circuits, except starting-motor and ignition circuits, should pass through protective devices connected to the battery feed side of switches. The circuits should preferably be arranged so that the opening of a protective device will not extinguish all the lights.

Flexible Steel Conduit and Ferrules for Electrical Uses

SAE Recommended Practice

Report of Electrical Equipment Division approved August 1916 and last revised January 1945.

[*This SAE Recommended Practice is intended primarily to provide for the classification and testing of flexible steel conduit for automotive electrical uses. Other features, such as the materials and methods of packing used for packed conduit, depend on the product supplied by individual manufacturers and are generally considered a matter of selection between the manufacturer and user of conduit. Although recommended types of packing are given, other types may be used with equally satisfactory results.*]

Flexible Steel Conduit—All conduit as received shall be measured without tension or compression which is what is known as natural lay. This conduit shall have a free elongation and compression of 10% from the normal natural length.

The interior of the conduit shall be free from burrs or sharp edges which may cause abrasion of the insulation on the wire or cable and from obstructions which might interfere with the easy introduction of the maximum-size wire or cable for which the conduit is intended.

To protect the wire or cable from abrasion and to prevent the conduit from unwinding, all exposed free ends when installed shall be bushed with suitable ferrules soldered to the conduit. Where taps or joints are made, suitable junction boxes shall be used and the ends of the conduit entering these boxes shall be carefully bushed with ferrules.

Tensile Test—A piece of conduit 12 in. long shall be placed in the jaws of a tensile-testing machine, 4 in. of each end being held by the jaws, leaving 4 in. between the jaws. Mandrels of the proper diameters shall be inserted in each end of the conduit

TABLE 1—*Flexible Galvanized Conduit, Unpacked*

NOM INSIDE DIAM, IN.	ACTUAL INSIDE DIAM, IN.		MAXIMUM OUTSIDE DIAM, IN.	MINIMUM THICKNESS OF STRIP, IN.	APPROX. WEIGHT, LB PER 100 FT EXTENDED	MINIMUM TENSION LOAD, LB	MINIMUM U-BEND LOAD, LB	MINIMUM BENDING RADIUS, IN.
	Min	Max						
3/16	0.184	0.196	0.278	0.010	3.8	75	30	1
1/4	0.245	0.260	0.345	0.010	4.5	100	40	1
5/16	0.308	0.323	0.413	0.010	5.4	110	40	1 1/8
3/8	0.368	0.388	0.478	0.010	6.2	125	40	1 1/4
7/16	0.431	0.451	0.551	0.011	8.2	150	45	1 1/4
1/2	0.493	0.513	0.633	0.011	9.0	175	60	1 3/8
9/16	0.556	0.576	0.696	0.011	10.4	185	75	1 5/8
5/8	0.618	0.638	0.758	0.011	11.3	200	75	1 3/4

to prevent distortion, and the conduit shall show no indication of yielding under a load less than that specified in Table 1.

Breaking Test—A piece of conduit shall be bent to a U shape between the flat heads of a compression-testing machine. The conduit shall be held in the machine in such a position that as the load is applied, the radius of the bend shall be decreased until the yield point is reached. The breaking load thus found shall be not less than that specified in Table 1.

Corrosion Test—Flexible steel conduit shall have a metallic coating which will withstand a 24-hr salt-spray test without the appearance of rust on any important surface. The pieces to be tested shall be free from all protective films other than the metallic coating.

The salt spray shall be a solution of salt (NaCl), 20% by weight, atomized continuously so as to give a visible fog. The temperature of the salt-spray test shall be approximately 70 F. In case the salt-spray test cannot be run continuously, the piece or pieces may by agreement be washed, dried, and stored in a dry place until the test is continued.

General Specifications—Flexible steel conduit shall be rust proofed with a metallic coating before forming and may be of either the packed or unpacked type. Packed conduit may have either asbestos or cotton packing. Asbestos packing is recommended when conduit is exposed to high temperatures, the packing consisting of a good grade asbestos yarn of sufficient size to insure reasonable and satisfactory tightness. When packing is used only to prevent rattles or looseness, cotton yarn is recommended.

Flexible steel conduit is designated by the nominal inside diameter, but the outside diameter must be held within the maximum shown in Table 1.

When conduit is supplied cut to length, the normal or natural-lay length shall apply and the ends shall be cut square and free from burrs or sharp edges which will interfere with assembling the conduit with the parts with which it is used.

All conduit shall be so formed that it will not unravel or show loose ends when cut and shall be free from any other defects which will affect its serviceability.

Flexible Conduit Ferrules—Dimensions for ferrules for flexible steel conduit are shown in Fig. 1 and Table 2.

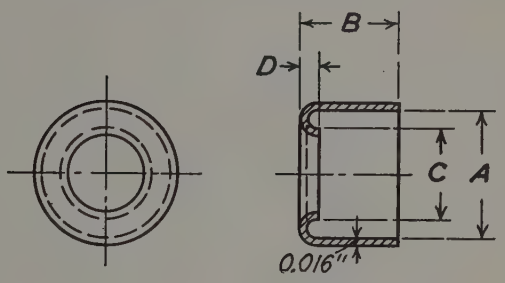


FIG. 1—FERRULE DIMENSIONS

TABLE 2—*Ferrules for Flexible Steel Conduit*

CONDUIT DIAMETER	INSIDE DIAMETER, *A*	LENGTH, *B*	SHOULDER DIAMETER, *C*	SHOULDER, *D*
3/16	0.285	1/4	0.188	1/16
1/4	0.355	1/4	0.250	1/16
5/16	0.425	1/4	0.313	1/16
3/8	0.485	3/8	0.375	1/16
7/16	0.555	3/8	0.438	1/16
1/2	0.630	3/8	0.500	1/16
5/8	0.760	1/2	0.625	3/32
3/4	0.930	1/2	0.750	3/32
7/8	1.040	1/2	0.875	3/32
1	1.175	5/8	1.000	1/8
1 1/4	1.435	5/8	1.250	1/8

Material—SAE 70, soft sheet brass, or SAE 1010, dead soft sheet steel is used for flexible conduit ferrules. All steel ferrules must be zinc or cadmium plated to withstand salt-spray test for 24 hr without showing rust.

Nonmetallic Conduit

SAE Recommended Practice

Report of Electrical Equipment Division approved March 1922 and last revised January 1945.

General Data—Nonmetallic flexible conduit or loom is recommended for use as an insulated covering giving mechanical protection over insulated wire, metal tubing, or other parts requiring a water-, oil-, and acid-proof covering resistant to fire or abrasion. It is also recommended for use as a covering for copper or other metal tubing to prevent crystallization and to eliminate rattles.

Construction—The loom shall be of single-wall construction, the material used to be strictly nonmetallic and of sufficient mechanical strength so that when formed or woven into a tubing it shall pass the tests for the size specified. Finished loom shall be free from obstruction and shall permit easy introduction of the maximum-size wire or other part for which it is normally suited. Loom in any length shall slip freely over a polished mandrel 12 in. long and equal in diameter to the minimum inside diameter specified. The dimensions of the standard sizes are listed in the accompanying table. Alternate dimensions for the sizes of 3/16, 1/4, and 3/8 in. indicated in Table 1 are for loom which can be used with standard ferrules.

TABLE 1—*Dimensions of Nonmetallic Conduit*

NOMINAL SIZE, IN.	INSIDE DIAMETER, IN.		OUTSIDE DIAMETER, IN.	
	Min	Max	Min	Max
3/16[a]	0.187	0.207	0.277	0.297
3/16	0.187	0.207	0.287	0.307
1/4[a]	0.250	0.270	0.340	0.360
1/4	0.250	0.270	0.350	0.370
5/16	0.312	0.332	0.412	0.432
3/8[a]	0.375	0.395	0.475	0.495
3/8	0.375	0.395	0.505	0.525
7/16	0.437	0.457	0.567	0.587
1/2	0.500	0.520	0.630	0.650
9/16	0.562	0.582	0.722	0.742
5/8	0.625	0.645	0.785	0.805
11/16	0.687	0.707	0.847	0.867
3/4	0.750	0.770	0.934	0.954
13/16	0.812	0.832	0.996	1.016
7/8	0.875	0.895	1.079	1.099
15/16	0.937	0.957	1.141	1.161
1	1.000	1.020	1.204	1.224

[a] For use with standard ferrules.

Saturation—For a fire-resistant loom, the inside and outside shall be thoroughly impregnated with an asphaltic compound or an equivalent water-, acid-, and fire-resisting compound. For a general-purpose loom, the inside and outside shall be thoroughly impregnated with an asphaltic compound or an equivalent water- and acid-resisting compound. For an oil-proof loom not affected by gasoline or baking varnish, the inside and outside shall be thoroughly impregnated with a gum saturator or its equivalent. The saturator, when dry, shall be free from tackiness and gummy deposits. This impregnation is introduced to prevent absorption of moisture, oil, or gasoline; to bind the material together to give the required wall strength; and to prevent fraying.

Finish—For a fire-resistant loom, the outer surface shall be thoroughly covered by an asphaltic or equivalent water-, acid-, and fire-resisting compound. For a general-purpose loom, the outer surface shall be thoroughly covered with at least two coats of black pyroxylin lacquer or its equivalent producing a good luster and a good bond to the fabric. For an oil-proof loom, the outer surface shall be thoroughly covered with at least two coats of black pyroxylin lacquer or its equivalent producing a good luster and a good bond to the fabric. The lacquer must be thoroughly dried before wrapping or boxing the loom for shipment. The use of heavy finishes or saturators to give artificial appearance is not permitted. The pyroxylin must be sufficiently plasticized so that it will not crack on a piece of loom kept three months at room temperature and then bent back sharply upon itself. Loom with finish of a higher luster than can be obtained with two coats of lacquer as specified above shall be considered special and should be covered by other specifications when required.

Tests—A 6-in. piece of loom totally immersed in water at 70 F for 24 hr and then blown out with a mild air current immediately after removing the water shall not have an increase in weight of more than 35%. The wall must not collapse when the loom is bent to a radius of five times the inside diameter at 70 F. The compound and finish must not crack open in this test.

The material in the wall of the loom shall not crack or break when a 3-in. length is flattened between two steel plates. When the inside diameter of loom is 3/8 in. or smaller, the distance between plates is to be 11/64 in. When the inside diameter of loom is over 3/8 in., the distance between plates is to be 9/32 in. The finish shall not show excessive cracking when loom is subjected to this test.

The polished mandrels used for checking the inside diameters shall show no sticking or discoloration up to 150 F.

Loom shall be capable of standing a tension test for 5 min without breaking or opening at any point as required in Table 2.

TABLE 2—*Tensile Requirements of Nonmetallic Conduit*[a]

LOOM, NOMINAL SIZE, IN.	MINIMUM TENSILE REQUIREMENT, LB
3/16	75
1/4	85
5/16 and 3/8	100
7/16 or larger	150

[a] The test piece shall be 6 in. long between suppports.

Additional Test for Oil-Proof and Fire-Resistant Loom—When a piece of loom is totally immersed in an equal mixture of cylinder oil, kerosene, and gasoline at 70 F for 5 min and then subjected to a temperature not exceeding 250 F for 1 hr, the saturating compound must not drip from the loom nor the finish show any appreciable defects.

Flame-resisting qualities shall be incorporated in the saturation or finish or both for the loom to pass the following test: The loom shall not convey fire nor support combustion for more than 1 min after five 15-sec applications of a standard test flame with intervals of 15 sec between applications. A standard test flame is the blue flame, about 5 in. high, produced by a 1/2-in. bunsen burner fed with ordinary illuminating gas at normal pressure. The loom shall be held vertically with either the lower or the upper end thoroughly sealed to prevent the passage of air, and the flame must be applied horizontally.

Insulated Cable

SAE Standard

Report of Electrical Equipment Division approved July 1921 and last revised by Electrical Equipment Technical Committee February 1950.

Low-Tension Cable

1. **General Specifications** (Rubber, Synthetic Rubber, or Thermoplastic Insulation).

Conductors—Conductors shall be bunched, concentric, or rope lay and as specified in Table 1 and shall be annealed copper wire in accordance with ASTM B 3—41. When coated wires are used, they must withstand the continuity test as specified under Section 2, Tests.

Insulation—Insulation shall be homogeneous in character and placed concentrically within commercial tolerance about the conductors. Insulation shall adhere closely to, but shall strip readily from the conductors, leaving them reasonably clean and in suitable condition for soldering.

Insulation thickness shall be in accordance with Table 1 for the various wire sizes and shall be determined by removing the outer covering, measuring the diameter over the insulation, then removing the insulation and measuring the diameter of the conductor. Half of the difference of the two measurements shall be considered as the wall thickness.

Braids—All braided coverings, irrespective of the type of finish or braid color, shall be thoroughly covered or saturated (depending upon the type of finish) with a firmly adhering compound which will present a finished appearance on unaided visual examination.

Braids shall be covered with a protective coating or impregnated with multiple coats of properly dried heat-, oil-, and water-resisting insulating varnish or when specified, impregnated with black weatherproof compound that thoroughly saturates the braid and that has an even and smooth finish. Adjacent layers of cable when wound on the reels shall not stick to one another at any temperature under 104 F (40 C).

2. **Tests**

Strand-Coating Tests—Tin tests shall be conducted on strands prior to stranding and shall be conducted as per ASTM B 33. Alloy coated wire shall conform to ASTM ES 1.

Physical Tests—A test specimen of rubber, synthetic rubber, or thermoplastic insulation selected in accordance with the SAE Standard on Classifications and Physical Requirements for Rubber Compounds (see section on sampling) shall be used. The dumbbell-cut sample shall have marks placed upon it 2 in. apart. The sample shall then be stretched at the rate of 12 in. per min. The tensile strength shall be calculated upon the original cross-section of the test specimen before stretching. Physical tests shall be made at room temperature of 70 F (21.1 C) plus or minus 5 deg. For the purpose of these tests, care must be used in cutting to

TABLE 1—*Types 1 and 2 Lighting and Starting-Motor Cables*

SAE Wire Size	Number of Wires	Nominal Size of Strand		Approximate Diameter of Stranded Conductor, In.	Area of Conductor, Cir Mils	Nominal Thickness of Insulated Wall	Maximum OD of Finished Cable
		AWG	In.				
20	10	30	0.0100	0.040	980	0.022	0.115
18	16	30	0.0100	0.050	1,568	0.022	0.135
16	19	29	0.0113	0.060	2,340	0.022	0.145
	16	28	0.0126				
14	26	28	0.0126	0.075	3,777	0.022	0.165
	19	27	0.0142				
12	41	28	0.0126	0.090	5,947	0.027	0.195
	19	25	0.0179				
10	65	28	0.0126				
	49	27	0.0142	0.115	9,443	0.031	0.230
	19	23	0.0226				
8	103	28	0.0126				
	49	25	0.0179	0.160	15,105	0.037	0.301
	19	21	0.0285				
6	172	28	0.0126				
	133	27	0.0142	0.210	26,440	0.047	0.360
	37	21	0.0285				
4	133	25	0.0179				
	61	22	0.0253	0.275	38,430	0.047	0.437
	49	21	0.0285				
2	259	26	0.0159	0.335	63,119	0.047	0.505
	127	23	0.0226	0.294			0.480
1	259	25	0.0179	0.375	80,010	0.047	0.557
	127	22	0.0253	0.330			0.503
0	259	24	0.0201	0.420	100,965	0.047	0.600
	127	21	0.0285	0.370			0.545
00	259	23	0.0226	0.475	126,822	0.047	0.655
	127	20	0.0320	0.415			0.590
000	259	22	0.0253	0.535	163,170	0.078	0.750
0000	418	23	0.0226	0.595	207,746	0.078	0.810

obtain samples of uniform cross-section, and no manufacturer shall be responsible for results obtained from samples imperfectly cut.

Physical Properties—For Type 1 cable insulated with rubber or synthetic compounds, the physical properties shall be as follows:

Tensile	1000 psi minimum
Elongation	150% minimum

For Types 2, 3, and 4, the properties shall be as follows:

Tensile	500 psi minimum
Elongation	200% minimum

For cable with thermoplastic insulation, all braided items, the physical properties shall be as follows:

Tensile	1000 psi minimum
Elongation	100% minimum

Oil Test for Rubber-Insulated Braided Cables—This test shall be made on all braided cables that have either a finishing compound lacquer or varnished finish. Weatherproof wax-treated cables shall not be subjected to these tests.

Samples of cables shall be immersed in a mixture of equal parts of SAE 30 engine oil and gasoline for a period of 24 hr without allowing the ends of the sample to become submerged. After this immersion, the finishing compound or varnish should not show signs of softening or absorption, and the diameter of the wire shall not show swelling of over 15%. The braid should then be removed and the insulation cut open. There should be no evidence that the liquid has penetrated to the strands. In making this test a shallow vessel shall be used to hold the mixture of engine oil and gasoline so that the sample of wire may be immersed without a sharp bend or the necessity of sealing the ends of the wire.

Note: For the purpose of qualifying the insulating compound, all of the following cable tests shall be conducted only on No. 16 gage cable.

High-Temperature Test (For Thermoplastic-Insulated Cables)—One inch of the insulation shall be removed from each end of a 24-in. sample of the finished cable. The sample shall be suspended around a cylindrical mandrel having a diameter of 6½ in. for No. 16 gage cable. Each end of the conductor shall have suspended from it a one pound weight. This condition shall be maintained for 120 hr in a circulating-air oven maintained at a temperature of 248 F. The samples shall be allowed to cool to room temperature. When cool, the weights shall be removed from the specimen and it shall be taken off the mandrel, bent in the reverse direction around a mandrel 3 in. in diameter at a rate not to exceed one complete turn per minute, and then be subjected to the following dielectric test. A specimen of the cable 2 ft long shall be formed into a loop. One inch of the insulation shall be removed from each end of the wire and the ends twisted together. The loop thus formed shall be immersed in salt water, containing 5% salt by weight, at room temperature, so that not more than 6 in. of each end of the specimen protrudes above the solution. After being immersed for 5 hr and while still immersed, the specimen shall withstand the application of 1000 v, rms, at 60 cps frequency between the conductor and the water for one min without rupture of the insulation.

Oil Test (For Thermoplastic-Insulated Cables)—A specimen 24 in. long shall be immersed to within 2 in. from the ends in a mixture of equal parts of kerosene and engine lubricating oil at a temperature of 118 to 122 F for a period of 20 hr. The sample shall then be removed from the solution, examined for deterioration of the insulating compound, and gaged for swelling.

The outside diameter of the insulation of the cable shall not increase more than 15%. The sample shall then be bent around a 3-in. diameter mandrel and checked for cracking; after the bend test the cable shall be given the dielectric breakdown test specified under High-Temperature Test.

Cold Test (For Thermoplastic-Insulated Cables)—A straight specimen shall be maintained at a temperature of −48 to −52 F for 1 hr. While still at this temperature, the sample shall be bent around a 3-in. diameter mandrel for at least 180 deg at the uniform rate of one complete turn per minute. The specimen is then subject to the dielectric breakdown test as outlined in the High-Temperature Test.

3. **Specification Types (Lighting and Starter Cables)**—Conductors shall be insulated in one of the following ways to be specified by the purchaser:

Insulation (rubber, synthetic rubber, or thermoplastic)
Type 1—Insulated-less braid, starter or ground use.
Type 2—Standard single braid, general-purpose use.
Type 3—Single braid, heavy-duty use.
Type 4—Double braid, extra-heavy-duty use.

Construction of the cables shall be as shown in Table 1. All braids in Types 2, 3, and 4 cables shall be coated with a flexible compound as specified in Section 1, General Specifications.

Note: Because of the special care needed in processing small conductors, it is recommended that nothing smaller than No. 16 wire be used in the wiring harnesses.

4. **Specification for Type 3 Cables**—The conductor and insulation shall be as shown in Table 1. The braid shall be made up of one-half paper twine and one-half cotton yarn The cable shall be braided such that all of the paper twine shall be in one direction and the cotton yarn braided in the opposite direction. The braid shall be finished or coated with a compound as specified in Section 1, General Specifications. Construction of these cables shall be as shown in Table 2.

TABLE 2—*Type 3 Cables (Single Braid, Paper and Cotton)*

NOMINAL SIZE AWG	SIZE, PLY, AND ENDS OF COTTON	MAXIMUM SIZE AND ENDS, PAPER YARN	16 CARRIER PICKS PER IN., MIN	MAXIMUM CABLE OD
18	14—1—4	0.028/1	10	0.155
16	30—2—4	0.028/1	13	0.170
14	or equiva-	0.028/1	13	0.190
12	lent[a] (all	0.028/1	16	0.230
10	sizes)	0.028/1	18	0.255

[a] If two- or three-end yarn is used, the picks per inch shall be changed such that a close weave is obtained.

5. **Specifications for Type 4 Cables**—The conductor, insulation, and first braid shall be as shown in Table 1 or Table 2 construction. The second braid covering shall be made up of one-half paper twine and one-half cotton yarn. The cable shall be braided such that all of the paper twine shall be in one direction and the cotton yarn braided in the opposite direction. The braid shall be finished or coated with a compound as specified in

Section 1, General Specifications. Construction of these cables shall be as shown in Table 3.

TABLE 3—*Type 4 Cables, Double Braided, Extra-Heavy Duty*

NOMINAL SIZE AWG	SIZE, PLY, AND ENDS OF COTTON	MAXIMUM SIZE AND ENDS, PAPER YARN	16 CARRIER PICKS PER IN., MIN	MAXIMUM CABLE OD
18	14—1—4	0.028/1	10	0.195
16	30—2—4	0.028/1	13	0.205
14	or	0.028/1	13	0.225
12	equivalent[a]	0.028/1	16	0.255
10	(all sizes)	0.028/1	16	0.290

[a] If two- or three-end yarn is used, the picks per inch shall be changed such that a close weave is obtained.

The conductors may be of bare copper, tin, or alloy-coated copper as required. A fibrous covering or paper shall be used as a separator between the bare conductors, if used, and the insulation.

When bunched stranding is used, the length of core lay for sizes Nos. 20 to 12 inclusive shall be 2 in. maximum. For Nos. 10 to 4 inclusive, the lay shall be 3 in. maximum. For larger cable the stranding shall be such that when the cable is bent around a 5-in. diameter mandrel, the cable shall not be injured.

Stranding may be bunched, concentric, or rope lay, and as specified in Table 1. The cross-sectional area of stranded conductors shall be not less than 98% of the values specified in the table, which allow for the effects of tinning and stranding.

High-Tension Cable (Braided Type)

This specification applies to braid-covered insulated cable for use as high-tension lead in motor-vehicle and tractor-engine ignition systems.

1. **General Specifications**

Conductor—The conductors shall be comprised of 19 strands No. 29 AWG annealed tinned copper wire having a lay twisted to the left as viewed from the observer. The circular mil area shall be within 2½% of the nominal cma. The diameter of the stranded group shall not exceed 0.060 in.

Insulation—A covering of insulating compound shall be applied directly over the conductor. The insulating compound shall adhere closely to, but shall strip readily from the wires of the conductor, leaving them reasonably clean. Each layer of the compound shall be homogeneous in character and placed concentrically around the conductor.

Braid—A protective braid shall be applied over the insulating compound. The braid shall be so finished as to be resistant to heat, oil, water, and gasoline. Adjacent layers of cable, when wound on a reel or when packed in sets, shall not stick to one another at any temperature under 105 F.

Size—The outside diameter of the cable shall be within 0.270 to 0.285 in. Cable may be slightly flattened or oval in section, but the two diameters measured 90 deg apart at any section must be within the values specified.

Date Marking (When Specified)—To identify the date of manufacture, three distinguishing colored threads shall be used in the braid. Two of these threads shall indicate the year of manufacture, the colors being:

1948—Yellow	1950—Red	1952—Yellow	1954—Red
1949—Green	1951—Black	1953—Green	1955—Black

For succeeding years this cycle will repeat.

The third thread shall indicate the quarter of the year of manufacture, the colors being:

First quarter—Red	Third quarter—Green
Second quarter—Black	Fourth quarter—Yellow

Optional Marking (When Specified)—The manufacturer's name, the quarter, and year shall be legibly and reasonably permanently marked on the outside of the cable at intervals not exceeding 2 ft; acceptable marking:

Manufacturer's name—1st Q—1949

2. **Tests**—Four samples of cable shall be subjected to each of the tests outlined below. All electrical tests shall be made with alternating current of 60 cps frequency. Voltages specified shall be mean effective values (root-mean-square).

Voltages should be increased from zero to the prescribed test values at a uniform rate of rise approximating but not exceeding 3 kv, rms, per sec.

High-Potential Test—One inch of insulation shall be removed from each end of an 18-in. length of the cable and the exposed ends of the conductor twisted together. The loop so formed shall be immersed in water at 68 F (20 C) ± 5 deg, so that 4 in. of each leg of the loop protrudes above the surface of the solution. After 24-hr immersion and while still immersed, a potential of 20,000 v shall be applied between the conductor of the cable and the water and shall be maintained for 20 min. The cable shall withstand this test without failure.

Corona Test—A 5-ft length of the cable, having a 5-lb weight attached to the free end, shall be wound 10 turns on a metal rod 1 in. in diameter, with adjacent turns touching. The cable shall then be secured to prevent slipping or release of tension. A potential of 10,000 v shall be applied between the conductor of the cable and the metal rod and maintained for 30 min. The potential shall then be raised to 20,000 v and maintained for 2 hr.

This test shall be started with cable and metal rod at a temperature of 68 F (20 C) ± 5 deg. The cable shall withstand this test without failure.

Low-Temperature Test—A sample of the cable, 5 ft in length, shall be stretched straight on a rack and subjected to a temperature of −10 F (−23.3 C) ± 5 deg for 12 hr. The cable shall then be wrapped around a 3-in. mandrel, with cable and mandrel at a temperature of −10 F. During this operation, the cable shall be protected from the warmth of the operator's hands by the operator's wearing heavy gloves. Cracking of the outer covering of the cable shall constitute failure.

Life-Cycle Test—One end of a 5-ft specimen shall be firmly attached to a suitable cylindrical mandrel with a diameter of ½ in.; a weight of 5 lb (avoirdupois) shall be firmly attached to the end of the specimen. The specimen shall be wound in a clockwise direction on the mandrel with the coils touching. It shall then be unwound and rewound in a counterclockwise direction so that the coils again touch. This procedure shall be repeated until no less than two bends in each direction have been imposed on the specimen. The specimen shall then be removed from the ½-in. mandrel and wound on a 1-in. mandrel so that there are 5 turns spaced ¾ in. apart. At the time of winding on the 1-in. mandrel, one end of the cable shall be firmly attached to the mandrel and the 5-lb weight attached to the outside of the other end of the specimen. After winding, a close-fitting brass sleeve with belled ends shall be placed over the wound mandrel. The

test specimen shall then be subjected to the procedures and conditions specified in Table 4 and shall not be removed from the 1-in. diameter mandrel until they have been completed.

TABLE 4—*Operations to be Performed and Conditions to be Maintained*

TIME CONSUMED, HR	FIRST 24-HR PERIOD	SECOND 24-HR PERIOD	THIRD 24-HR PERIOD	3½-HR PERIOD
3	Rest	Rest	Drain	Drain
½	Corona test 15 kv	Corona test 15 kv	Corona test 15 kv	Corona test 15 kv
½	Rest	Rest	Rest	—
20	Bake in oven at 176 ±20 F.	Soak in 5% sodium chloride solution at room temperature, ends protruding not more than 8 in. nor less than 4 in.	Soak in solu- of 1 part kerosene, 1 part motor fuel, 2 parts engine SAE 30 oil,[a] ends protruding not more than 8 in. nor less than 4 in.	—

[a] Kerosene conforming with Federal Specification VV-K-211.

Tinning Test should be conducted on strands prior to stranding and shall be conducted according to ASTM B 33.

High-Tension Cable, Synthetic Sheath, Waterproof Type

This specification covers 7-mm diameter synthetic-sheath high-tension cable for use as ignition cable leads in motor-vehicle, or tractor-engine ignition systems.

1. **General Specifications**

Conductor—The conductor shall be comprised of 19 strands No. 29 AWG annealed tinned copper wire having a lay twisted to the left as viewed from the observer. The cma shall be within 2½% of the nominal cma. The diameter of the stranded group shall not exceed 0.060 in.

Insulation—A homogeneous insulating compound shall be applied concentrically over the conductor. The insulation shall adhere closely to, but shall strip readily from the conductor, leaving strands of wire reasonably clean. The thickness of insulating compound shall be such that it will meet the tests specified herein.

Braid—An open-weave braid of suitable textile over the insulating compound is optional.

Synthetic Sheath—A synthetic-rubber sheath shall be applied concentrically over the insulation or over the braid, if used. It shall be so compounded as to meet the tests specified herein. Adjacent layers of cable, when wound on reel or coil or packed in sets, shall not stick to one another at any temperature under 120 F.

Size—The outside diameter of the cable shall be within 0.270 and 0.290 in. Cable may be slightly flattened or oval in section, but the two dimensions measured 90 deg apart at any section must be within the values specified.

Date Marking (When Specified)—The manufacturer's name, the quarter, and year shall be legibly and reasonably permanently marked on the outside of the cable at intervals not exceeding 2 ft; acceptable marking:

Manufacturer's name—1st Q—1949

2. **Tests**—Four samples of a suitable length of cable, or length as specified, shall be subjected to each test outlined below. Failure of more than one sample on any one test may be considered cause for rejection of the lot from which samples were selected.

All electrical tests shall be made with 60-cycle alternating current. The voltage specified shall be mean effective values (root-mean-square).

Voltage shall be increased from zero to the prescribed test value at a uniform rate of rise approximating but not exceeding 3 kv per sec or as otherwise specified.

Waterproof Test—One inch of insulation shall be removed from each end of an 18-in. length of cable and the ends twisted together forming a loop. The specimen shall then be totally immersed, ends down, in distilled water at 185 ± 6 F for 2 hr, after which time the specimen shall be removed and suspended in a grounded, 5% (by weight) sodium chloride solution, with 3 ± ¼ in. of the ends protruding. After specimens have been in the solution 30 min, a potential of 1000 v is to be applied from the bare ends to ground, and the potential increased at a rate of approximately 1000 v per 5 sec, to 15,000 v. The potential shall be held at 15,000 v for 5 min. Burning over the ends or rupture of the insulation shall indicate failure.

Life-Cycle Test—One end of a suitable length of cable shall be secured to a ½-in. diameter mandrel. A weight of 10 lb shall be attached to the free end. The mandrel and cable specimen shall then be rotated. Five complete turns shall be wound around the mandrel, coils touching. The cable shall then be unwound and rewound in the opposite direction. The complete winding cycle shall be performed twice.

The specimen shall then be wound on a 1-in. diameter mandrel so that there are 5 turns spaced ¾ in. apart. A 5-lb weight shall be attached to the free end during the winding cycle. The specimen shall be suitably secured to the mandrel to prevent unwinding during the test cycle. The mandrel and specimen shall then be placed in a snug-fitting, belled metal shield. The specimen with mandrel and shield shall be subjected to the following tests:

(a) Heat 5 hr at 250 ± 3 F. Remove from the oven and immerse in water maintained at 120 ± 3 F for a period of 18 hr. Remove and drain for 30 min. Subject specimen to 15,000 v applied between conductor and sheath for 30 min. Follow by

(b) Immerse in SAE 30 oil maintained at 194 ± 5 F for 18 hr. Remove and drain 30 min. Subject specimen to 15,000 v applied between conductor and sheath for 30 min. Follow by

(c) Immerse in kerosene[1] for a period of 18 hr at room temperature. Drain for 4 hr. After completion of tests, the insulation shall not crack, rupture, show excessive swelling, or other evidence of damage.

High-Temperature Test—Suitable lengths of cable shall be suspended straight in a ventilated oven maintained at a temperature of 250 ± 3 F for 48 hr. The specimen shall then be removed from the oven, allowed to cool to room temperature, then wrapped 360 deg around a ½-in. mandrel. Cracking of the outer jacket shall constitute failure.

Low-Temperature Test—Suitable lengths of straight specimens shall be placed in a cold chamber maintained at −30 ± 1 F for 24 hr. Without removing from the cold chamber, wrap speci-

[1] Kerosene conforming with Federal Specification VV-K-211.

men 360 deg around a 3-in. diameter mandrel which has also been subjected to the same time and temperature as the specimen. Cracking of the outer jacket shall constitute failure.

Hot-Oil Test—Twenty-inch specimens shall be immersed in SAE 30 oil maintained at a temperature of 250 ± 5 F for a 40-hr period. The ends of the specimens shall protrude 3 in. above the oil and be 1 in. apart. The oil shall be circulated during the test. Remove from oil and allow to cool to room temperature, wipe free of oil and wrap center portion 360 deg around a ½-in. diameter mandrel against curvature of bend. Excessive swelling, cracking, or rupture of jacket shall constitute failure.

Braided Grounding Straps

The copper-braided straps listed in Table 5 are intended for battery-ground and engine-ground straps.

Individual Strands—Strands shall be annealed copper wire in accordance with ASTM B 3—41. They may be either tinned, lead, alloy coated, or uncoated as specified.

The straps shall be braided in conventional manner of interlocking, the braider carriers shall travel over and under in a uniform pattern. The round braided sleeve shall be rolled flat to the approximate width as indicated in Table 5. The width may be varied by changing the pressure of the rollers.

TABLE 5—*Construction Details of Braided Grounding Straps*

GAGE SIZE IDENTIFICATION	APPROXIMATE CIRCULAR MIL AREA	NO. OF CARRIERS	MINIMUM STRANDS PER CARRIER	MAXIMUM STRAND GAGE SIZE	APPROXIMATE WIDTH
9	12,060	24	5	30	7/16
6	26,532	24	11	30	5/8
4	38,592	24	16	30	7/8
		48	8	30	
3	48,240	24	20	30	7/8
		48	10	30	
2	65,124	24	27	30	15/16
1	77,184	24	32	30	15/16
1	82,008	48	17	30	15/16
0	106,128	48	22	30	15/16
00	130,248	48	27	30	15/16

7-Conductor Jacketed Cable for Truck and Trailer Connections

SAE Recommended Practice

Report of Electrical Equipment Technical Committee approved January 1951.

Conductor

One (center) 10 gage—105 strands of #30 tinned annealed copper wire, twisted with a lay of 1.50 in., wire tinned according to ASTM B 33.

Six 12 gage—65 strands of #30 tinned annealed copper wire, twisted with a lay of 1.50 in., wire tinned according to ASTM B 33.

Steel strands may be added to increase flexibility life.

Insulation—Each 12-gage conductor shall be insulated with a nominal 1/32-in. wall and the 10-gage conductor insulated with a nominal 0.021-in. wall of compound meeting the specifications given in Table 1.

TABLE 1—*Specifications for Insulation Compound*[a]

	AT 60 C
Recovery, in.	5 in. str, ½
Elongation, %	250
Tensile Strength, psi	600[b]
Oxygen-Bomb Aged (96 hr at 70 C, 300 psi), Elongation, % original	70[c]
Oxygen-Bomb Aged (96 hr at 70 C, 300 psi), Tensile, % original	70[b]

[a] Underwriters' physical requirements for insulates on approved cables.
[b] Tensile tests are not made on insulation less than 1/32 in.
[c] Except for conductor insulation less than 1/32 in., this may not be less than 65%. Sum of tensile and elongation must be 140%.

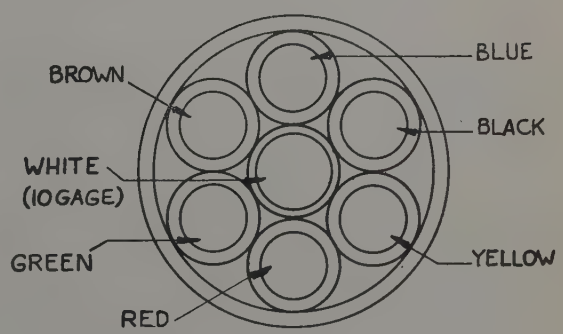


FIG. 1—COLORS OF INSULATING COMPOUND

The colors of the insulating compound shall be in accordance with Fig. 1.

Finish and Filler—The conductor shall be twisted with a maximum lay of 4 in. A suitable filler may be applied in twisting

so as to fill the interstices between the conductors to produce a circular cross-section. A suitable separator over the cable conductors is optional.

Protective Sheath—A 1/16-in. minimum thickness jacket shall be applied over the cable conductors or serve, if used. The jacket compound shall meet the specifications given in Table 2.

Cold Test—A suitable length of cable shall be subjected to −20 F for a period of 4 hr. While still in the cold cabinet, it shall be bent 360 deg around a 3-in. diameter mandrel. Jacket insulation must not crack.

Finish—The finish of the cable shall be smooth and free from defects, and adjacent layers shall not stick together when wound around a spool at any temperature below 120 F. The finish diameter of the cable is to be 0.690 ± 0.020 in.

Inspection—Cables shall be free from open circuits or twisted conductor splices.

TABLE 2—*Specifications for Jacket Compound*[a]

	AT 60 C
Recovery, in.	6 in. str, 3/8
Elongation, %	300
Tensile Strength, psi	1500
Oxygen-Bomb Aged (96 hr at 70 C, 300 psi), Elongation, % original	70[b]
Oxygen-Bomb Aged (96 hr at 70 C, 300 psi), Tensile, % original	70[b]
Air-Oven Aged (168 hr at 70 C), Tensile and Elongation, % original	70[b,c]
Oil Immersed (18 hr at 121 C), Tensile and Elongation, % original	60[c]

[a] Underwriters' physical requirements for insulates on approved cables.
[b] Except for conductor insulation less than 1/32 in., this may not be less than 65%. Sum of tensile and elongation must be 140%.
[c] SO and SJO types only.

Electrical Connector for Truck-Trailer Jumper Cable

SAE Recommended Practice

Report of Electrical Equipment Technical Committee approved January 1951. This SAE Recommended Practice conforms to ATA Recommended Equipment Specification E-1—1950.

Scope—This SAE Recommended Practice covers the details, dimensions, and design of the parts of both cable plug and trailer receptacle which must mate properly to permit interchangeable use of different makes of connectors. Also included is a uniform wiring pattern for trailer electrical circuits and their connection to specific contacts in the connector socket and cable plug. (See SAE Recommended Practice for Semi-Trailer Brake-Connection Locations.)

Definitions—The receptacle is the complete unit permanently attached to the nose of the trailer, consisting of connector socket, its external housing, and a cover which latches to the cable plug.

The connector socket is that portion of the receptacle which carries the external contacts.

The cable plug is the round plug attached to the end of the towing vehicle's electric jumper cable and containing the internal contacts.

The wire color code refers to color identifying marking in or on the outside insulation of the wire conductors.

Trailer Wiring Circuits

Conductor Number	*Wire Color*	*Lamp and Signal Circuits*
1	White	Ground return to towing vehicle
2	Black	Marker and clearance lamps (required by ICC at or near top of trailer)
3	Yellow	Left-turn directional signal
4	Red	Stop lamp
5	Green	Right-turn directional signal
6	Brown	Tail lamp, three-bar marker lamps, and other clearance or marker lamps
7	Blue	Auxiliary circuits

Details of Receptacle—Fig. 1 gives connector-socket details.

The receptacle shall be provided with a weather-tight cover attached to the connector socket or external housing and provided with a latching device which shall make engagement with the back end of the index lug of the cable plug (Fig. 2). The receptacle cover shall be so constructed that it will latch properly without

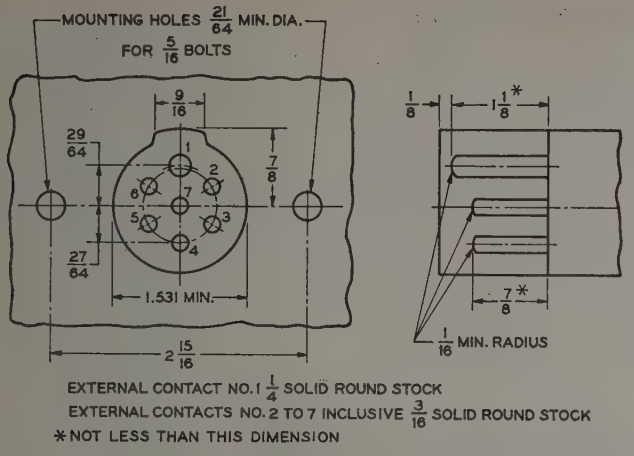


FIG. 1—CONNECTOR SOCKET
The contacts are numbered clockwise when looking into the open end of the socket

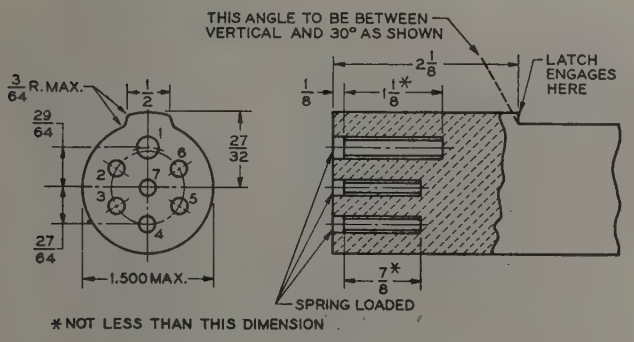


FIG. 2—CABLE PLUG
The contacts are numbered counterclockwise when looking into the open end of the cable plug

interference to a cable plug not more than 1½ in. in diameter, regardless of the plug's length, when such a plug is properly engaged with the connector socket.

Flush mounted receptacles are preferred.

The connector socket shall be so constructed that No. 12 B&S gage wire may be connected to all the 3/16-in. external contacts and No. 10 B&S gage wire may be connected to the ¼-in. external contact (Fig. 1). (In cases where the ¼-in. contact is directly grounded to the receptacle, no provision for attaching a wire need be provided.)

All electric current carrying parts of the connector socket shall be made of brass or bronze.

All steel parts of the receptacle shall be protected against rusting by a protective coating of metal.

Details of Cable Plug—Fig. 2 gives cable-plug details.

The force required to connect or disconnect the cable plug and the receptacle or connector socket shall be, within reasonable limits, consistent with providing proper electrical connections between the external and internal contacts.

An assembled cable plug and trailer jumper cable shall be so constructed that they will not be damaged by resisting a straight pull of at least 150 lb applied to the jumper cable. All cable plugs shall incorporate a strain-relief device (to ease the tension on the electrical connections between the internal contacts and the jumper cable conductors) capable of resisting without damage a tension of 150 lb applied to a specific cable properly attached to the plug.

The cable plug shall incorporate an index lug which shall have the dimensions shown in Fig. 2 and which shall also make provision for engaging the latch of the cover as specified in Details of Receptacle.

The plug shall be so constructed that No. 12 B&S gage wire may be connected to all the 3/16-in. internal contacts and No. 10 B&S gage wire may be connected to the ¼-in. internal contact.

All electric current carrying parts of the cable plug shall be made of brass or bronze.

All steel parts of the cable plug shall be protected against rusting by a protective coating of metal.

Location of Receptacle on Trailer—The trailer electric jumper-cable receptacle shall be located approximately 18 in. above the fifth-wheel plate on the front centerline of the nose of the trailer. The receptacle shall be above and between any brake-hose couplers mounted on the nose of the trailer. The receptacle shall be mounted so that the axis of the connector socket does not incline above the horizontal at the open end, and is parallel with the longitudinal centerline of the trailer.

Cable Terminals

SAE Standard

Report of Electrical Equipment Division approved August 1918 and last revised by Electrical Equipment Technical Committee January 1946.

[*This SAE Standard was set up to eliminate unnecessary variations in sizes and types of terminals for electrical connections. The types and number of sizes in each type are considered adequate to meet all requirements in automotive equipment. In order to keep down initial cost, the terminals have been laid out to require a minimum number of die sets.*]

Terminals shall be free from burrs, sharp corners, corrosion, or any foreign matter. The temper of the terminals shall be sufficiently soft to permit the terminal's being assembled with the wings closed and not show any fracture or cracks which would impair the strength of the assembly.

The tolerance on fractional dimension shall be ±0.010 in.

Materials should be brass or copper.

(*Continued on next page.*)

TABLE 1—*Stud or Screw and Hole or Slot Sizes*

SAE Number	STUD OR SCREW SIZE		A, HOLE OR SLOT SIZE FOR EYELET OR SPADE TERMINAL		SAE Number	STUD OR SCREW SIZE		A, HOLE OR SLOT SIZE FOR EYELET OR SPADE TERMINAL	
	Nom	Max	Min	Max		Nom	Max	Min	Max
1	4	0.1120	0.123	0.127	6	5/16	0.3125	0.342	0.346
2	6	0.1380	0.144	0.148	7	3/8	0.3750	0.404	0.408
3	8	0.1640	0.170	0.174	8	7/16	0.4375	0.466	0.472
4	10	0.1900	0.201	0.205	9	1/2	0.5000	0.528	0.534
5	1/4	0.2500	0.279	0.283					

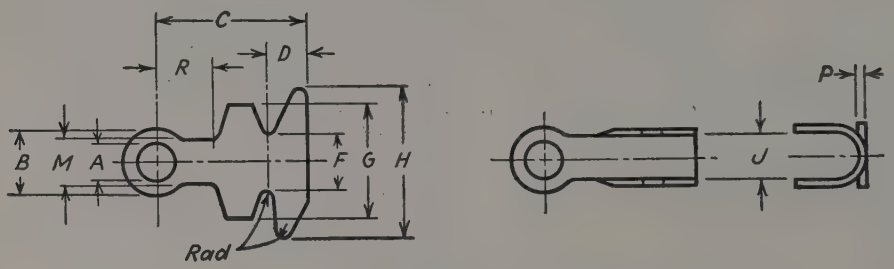


FIG. 1—STRAIGHT-TYPE EYELET TERMINAL

TABLE 2—*Straight-Type Eyelet Terminals*

SAE Number	SCREW SIZE	A Min	A Max	B	C	D	F	G	H	J	M	P	R
To use on SAE No. 18 and No. 20 wire													
A001	4	0.123	0.127	1/4	1/2	1/8	3/16	3/8	15/32	1/8	5/32	0.032	3/16
A002	6	0.144	0.148										
A003	8	0.170	0.174	11/32	1/2	1/8	3/16	3/8	15/32	1/8	5/32	0.032	3/16
A004	10	0.201	0.205										
A005	1/4	0.279	0.283	15/32	5/8	1/8	3/16	3/8	15/32	1/8	5/32	0.032	5/16
A006	5/16	0.342	0.346										
To use on SAE No. 14 and No. 16 wire													
B101	4	0.123	0.127	9/32	3/4	7/32	3/16	1/2	21/32	3/16	3/16	0.032	1/4
B102	6	0.144	0.148										
B103	8	0.170	0.174	11/32	13/16	7/32	1/4	1/2	21/32	3/16	3/16	0.032	5/16
B104	10	0.201	0.205										
B105	1/4	0.279	0.283	9/16	7/8	7/32	1/4	1/2	21/32	3/16	1/4	0.032	3/8
B106	5/16	0.342	0.346	11/16	1	7/32	1/4	1/2	21/32	3/16	1/4	0.032	7/16
B107	3/8	0.404	0.408	11/16	1 1/32	7/32	1/4	1/2	21/32	3/16	1/4	0.032	1/2
To use on SAE No. 10 and No. 12 wire													
B203	8	0.170	0.174	11/32	13/16	7/32	5/16	5/8	27/32	1/4	1/4	0.040	5/16
B204	10	0.201	0.205										
B205	1/4	0.279	0.283	9/16	7/8	7/32	5/16	5/8	27/32	1/4	1/4	0.040	3/8
B206	5/16	0.342	0.346	11/16	1	7/32	5/16	5/8	27/32	1/4	5/16	0.040	7/16
B207	3/8	0.404	0.408	11/16	1 1/32	7/32	5/16	5/8	27/32	1/4	5/16	0.040	1/2
B208	7/16	0.466	0.472	11/16	1 1/8	7/32	5/16	5/8	27/32	1/4	5/16	0.040	5/8
B209	1/2	0.528	0.534	13/16	1 5/32	7/32	5/16	5/8	27/32	1/4	5/16	0.040	5/8
To use on SAE No. 8 wire													
B304	10	0.201	0.205	9/16	1 1/8	11/32	3/8	13/16	1	5/16	5/16	0.045	5/16
B305	1/4	0.279	0.283	9/16	1 1/8	11/32	3/8	13/16	1	5/16	5/16	0.045	3/8
B306	5/16	0.342	0.346	11/16	1 3/16	11/32	3/8	13/16	1	5/16	5/16	0.045	7/16
B307	3/8	0.404	0.408	13/16	1 7/32	11/32	3/8	13/16	1	5/16	3/8	0.045	1/2
B308	7/16	0.466	0.472	13/16	1 5/16	11/32	3/8	13/16	1	5/16	3/8	0.045	5/8

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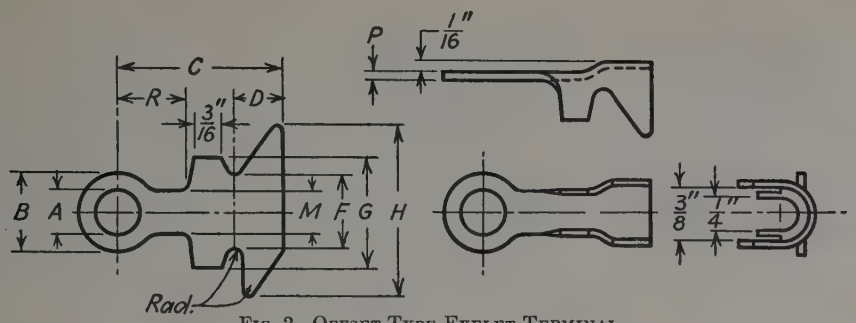

FIG. 2—OFFSET-TYPE EYELET TERMINAL

TABLE 3—*Offset-Type Eyelet Terminals*

SAE Number	SCREW SIZE	A		B	C	D	F	G	H	M	P	R
		Min	Max									
To use on SAE No. 4 and No. 6 wire												
C404	10	0.201	0.205	9/16	1 1/16	11/32	1/2	13/16	1 1/4	5/16	0.045	3/8
C405	1/4	0.279	0.283	9/16	1 1/8	11/32	1/2	13/16	1 1/4	5/16	0.045	7/16
C406	5/16	0.342	0.346	9/16	1 3/16	11/32	1/2	13/16	1 1/4	5/16	0.045	1/2
C407	3/8	0.404	0.408	13/16	1 7/32	11/32	1/2	13/16	1 1/4	3/8	0.045	1/2
C408	7/16	0.466	0.472	13/16	1 5/16	11/32	1/2	13/16	1 1/4	3/8	0.045	5/8
C409	1/2	0.528	0.534	15/16	1 11/32	11/32	1/2	13/16	1 1/4	3/8	0.045	5/8

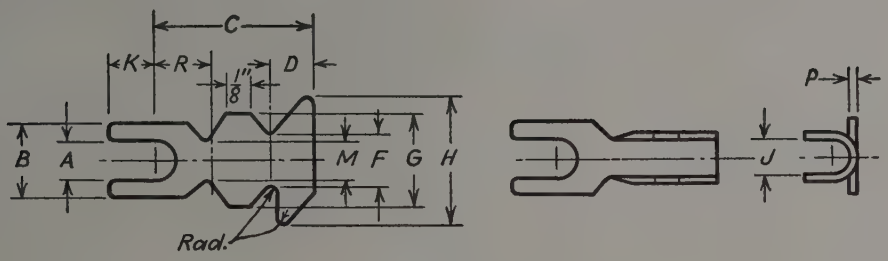

FIG 3—STRAIGHT-TYPE SPADE TERMINAL

TABLE 4—*Straight-Type Spade Terminals*

SAE Number	SCREW SIZE	A		B	C	D	F	G	H	J	K	M	P	R
		Min	Max											
To use on SAE No. 18 and No. 20 wire														
H003	8	0.170	0.174	0.365	9/16	1/8	3/16	3/8	15/32	1/8	3/16	5/32	0.032	1/4
H004	10	0.201	0.205	0.375										
To use on SAE No. 14 and No. 16 wire														
H103	8	0.170	0.174	0.365	13/16	7/32	1/4	1/2	21/32	3/16	1/4	3/16	0.032	5/16
H104	10	0.201	0.205	0.375										
To use on SAE No. 10 and No. 12 wire														
H203	8	0.170	0.174	0.365	13/16	7/32	5/16	5/8	27/32	1/4	1/4	1/4	0.040	5/16
H204	10	0.201	0.205	0.375										

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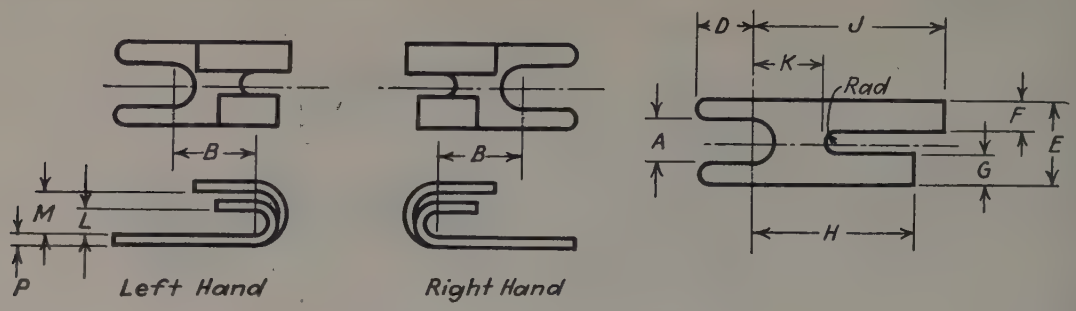

FIG. 4—SIDE-TYPE SPADE TERMINAL

TABLE 5—*Side-Type Spade Terminals*

SAE Number	SCREW SIZE	A		B	D	E	F	G	H	J	K	L	M	P
		Min	Max											
To use on SAE No. 14 wire or smaller														
M103	8	0.170	0.174	11/32	1/4	0.370	5/32	5/32	39/64	23/32	9/32	5/64	5/32	0.032
M104	10	0.201	0.205			0.375								
To use on SAE No. 10 and No. 12 wire														
M203	8	0.170	0.174	11/32	1/4	0.370	1/8	5/32	47/64	7/8	5/16	1/8	7/32	0.040
M204	10	0.201	0.205			0.375								

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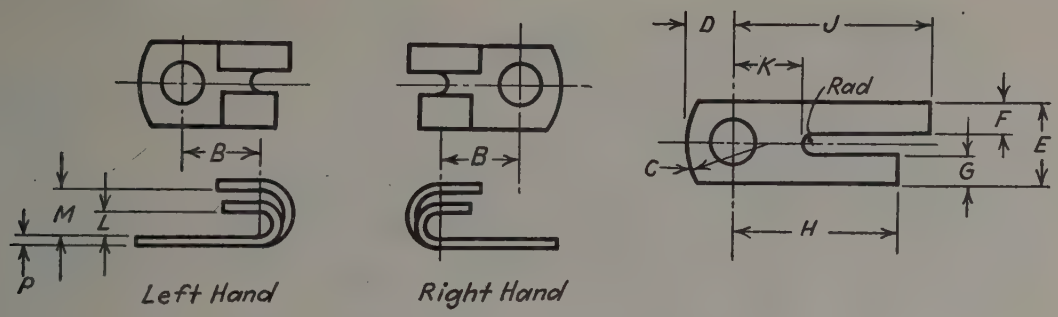

FIG. 5—SIDE-TYPE EYELET TERMINAL

TABLE 6—*Side-Type Eyelet Terminals*

SAE Number	SCREW SIZE	A Min	A Max	B	C	D	E	F	G	H	J	K	L	M	P
To use on SAE No. 14 wire or smaller															
K101	4	0.123	0.127	11/32	5/16	5/32	0.308 0.313	7/64	9/64	39/64	23/32	9/32	5/64	5/32	0.032
K102	6	0.144	0.148												
K103	8	0.170	0.174	11/32	3/8	3/16	0.370 0.375	5/32	5/32	39/64	23/32	9/32	5/64	5/32	0.032
K104	10	0.201	0.205												
K105	1/4	0.279	0.283	13/32	1/2	1/4	0.495 0.505	3/16	1/4	43/64	25/32	9/32	5/64	5/32	0.032
K106	5/16	0.342	0.346	1/2	5/8	5/16	0.620 0.630	1/4	9/32	25/32	15/16	1/2	5/64	5/32	0.040
K107	3/8	0.404	0.408	5/8	3/4	3/8	0.745 0.755	5/16	11/32	29/32	1 1/16	5/8	5/64	5/32	0.040
To use on SAE No. 10 and No. 12 wire															
K203	8	0.170	0.174	11/32	3/8	3/16	0.370 0.375	1/8	5/32	47/64	7/8	5/16	1/8	7/32	0.040
K204	10	0.201	0.205												
K205	1/4	0.279	0.283	9/16	1/2	1/4	0.495 0.505	3/16	7/32	61/64	1 5/32	1/2	1/8	7/32	0.040
K206	5/16	0.342	0.346	9/16	5/8	5/16	0.620 0.630	1/4	9/32	61/64	1 5/32	1/2	1/8	7/32	0.045
K207	3/8	0.404	0.408	11/16	3/4	3/8	0.745 0.755	5/16	11/32	1 3/32	1 5/16	5/8	1/8	7/32	0.045
To use on SAE No. 6 and No. 8 wire															
K306	5/16	0.342	0.346				0.745								
K307	3/8	0.404	0.408	23/32	3/4	3/8	0.755	5/16	11/32	1 5/16	1 17/32	21/32	7/32	5/16	0.045
K308	7/16	0.466	0.472												

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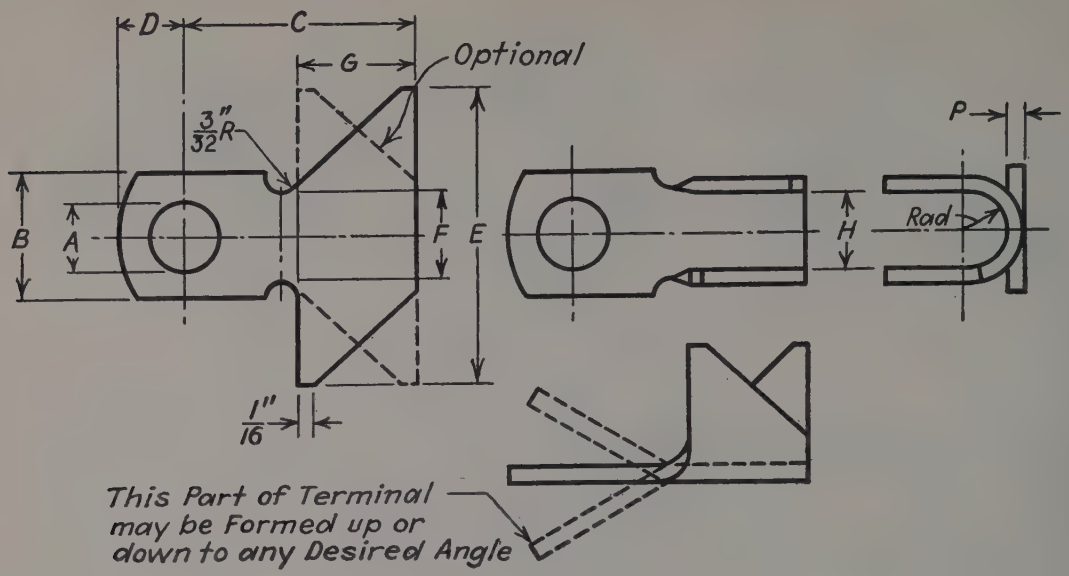

FIG. 6—END-TYPE STARTING-CABLE TERMINAL

TABLE 7—*End-Type Starting-Cable Terminals*

SAE Number	SCREW SIZE	A		B	C	D	E	F	G	H	P	MATERIAL
		Min	Max									
To use on SAE No. 4 and No. 6 cable												
N405	1/4	0.279	0.283	9/16	1 1/4	1 1/32	1 1/4	5/16	5/8	3/8	0.091	Brass
N406	5/16	0.342	0.346	11/16	1 1/4	1 1/32	1 1/4	5/16	5/8	3/8	0.091	
N407	3/8	0.404	0.408	11/16	1 1/4	1 1/32	1 1/4	5/16	5/8	3/8	0.091	
N408	7/16	0.466	0.472	3/4	1 1/4	1 1/32	1 1/4	5/16	5/8	3/8	0.091	
To use on SAE No. 1 and No. 2 cable												
N505	1/4	0.279	0.283	9/16	1 1/4	1 1/32	1 5/8	1/2	5/8	1 3/32	0.091	Brass
N506	5/16	0.342	0.346	11/16	1 1/4	1 1/32	1 5/8	1/2	5/8	1 3/32	0.091	
N507	3/8	0.404	0.408	11/16	1 1/4	1 1/32	1 5/8	1/2	5/8	1 3/32	0.091	
N508	7/16	0.466	0.472	3/4	1 1/4	1 1/32	1 5/8	1/2	5/8	1 3/32	0.091	
To use on SAE No. 0 and No. 00 cable												
N606a	5/16	0.342	0.346	3/4	1 5/16	3/8	1 3/4	9/16	11/16	1/2	0.091	Copper
N606b	5/16	0.342	0.346	3/4	1 3/4	3/8	1 3/4	9/16	11/16	1/2	0.091	
N607a	3/8	0.404	0.408	3/4	1 5/16	3/8	1 3/4	9/16	11/16	1/2	0.091	
N607b	3/8	0.404	0.408	3/4	1 3/4	3/8	1 3/4	9/16	11/16	1/2	0.091	
N608a	7/16	0.466	0.472	3/4	1 5/16	3/8	1 3/4	9/16	11/16	1/2	0.091	
N608b	7/16	0.466	0.472	3/4	1 3/4	3/8	1 3/4	9/16	11/16	1/2	0.091	

Electrical-Instrument Binding Posts

SAE Recommended Practice

Report of Electrical Equipment Division approved June 1927 and last revised January 1945.

[*This SAE Recommended Practice relates primarily to electrical-instrument binding posts used in motor vehicles.*]

The binding posts of electrical instruments for standard service requirements shall be No. 10—32 NF—2 or No. 8—32 NF—2 American Standard Fine Thread or both. For heavy-duty requirements, the binding posts shall be ¼"—28 N—2 American Standard form. Both sizes shall be Class 2 fit.

Sockets, Plugs, and Caps

SAE Standard

Report of Electrical Equipment Division approved August 1915 and last revised by Lighting Technical Committee January 1946.

All dimensions for the following plugs and sockets are the same as those given in Figs. 1 and 2, except where otherwise indicated.

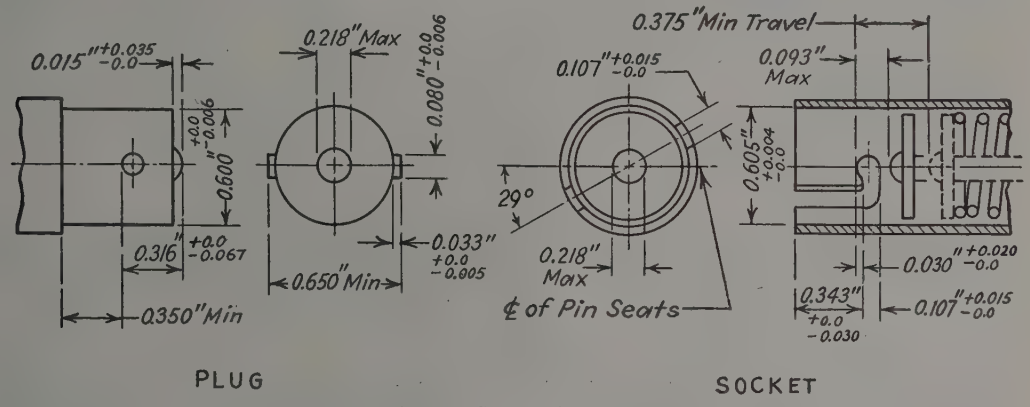

Fig. 1—Single Contact

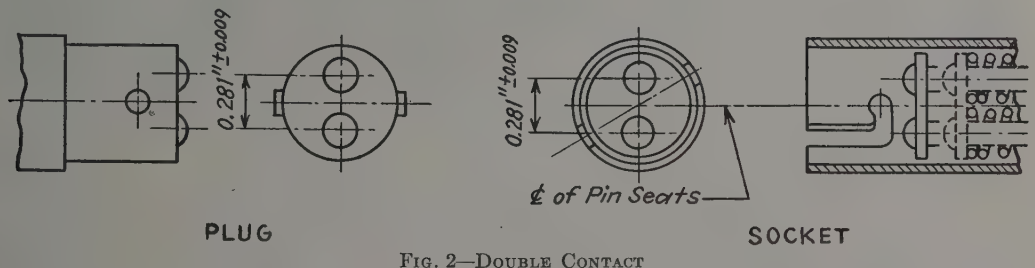

Fig. 2—Double Contact

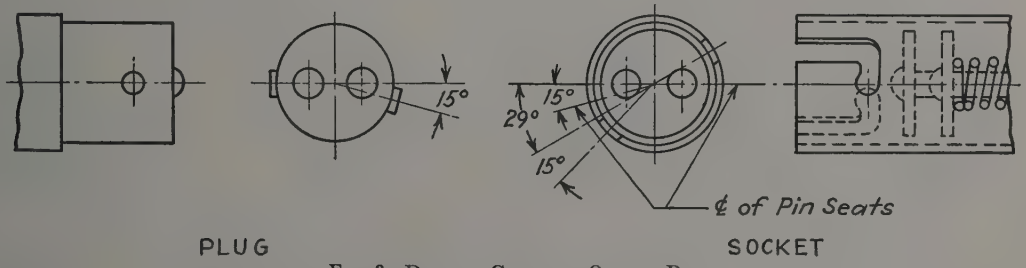

Fig. 3—Double Contact, Offset Pin

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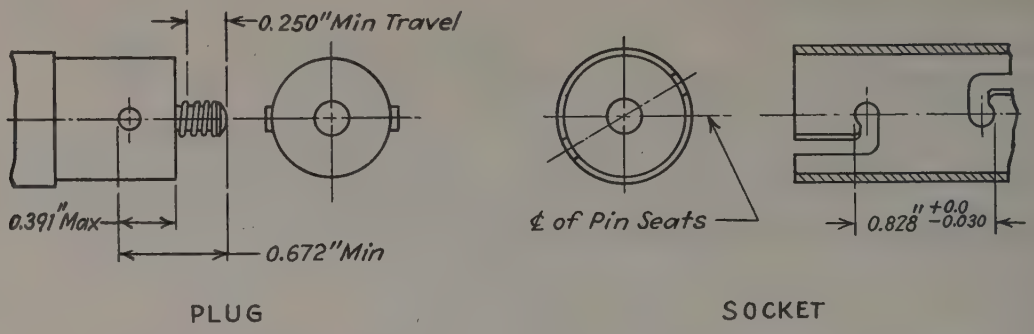

FIG. 4—DOUBLE END, SHORT

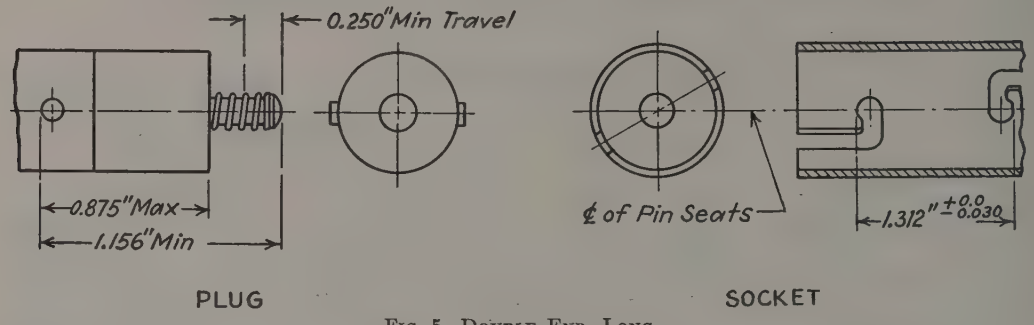

FIG. 5—DOUBLE END, LONG

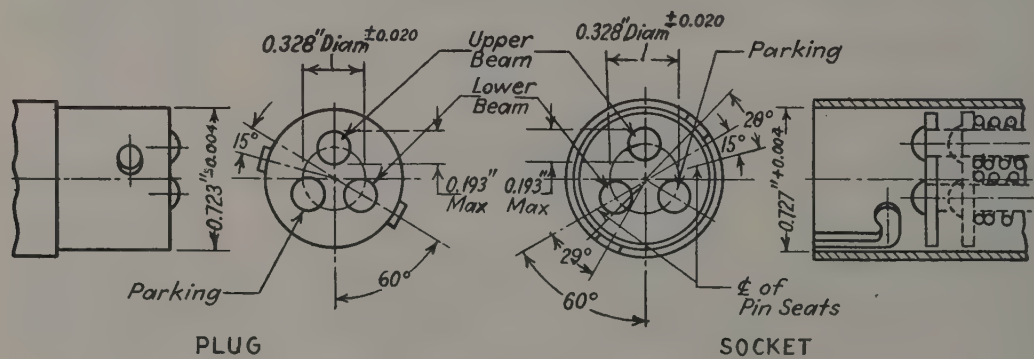

FIG. 6—THREE-WAY OFFSET PINS, LARGE

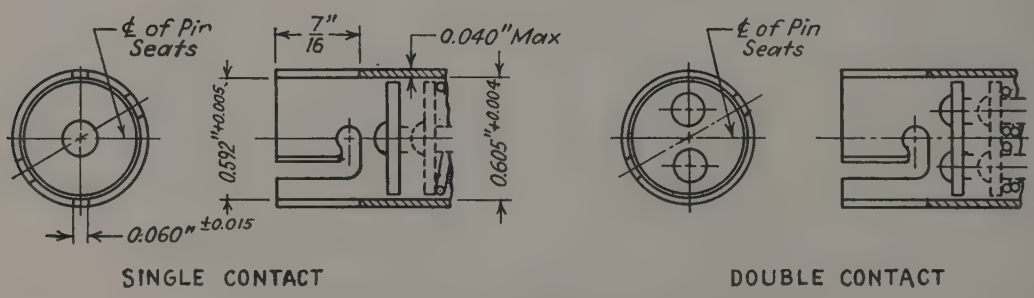

FIG. 7—BAYONET SOCKETS, CLOSED-IN TYPE

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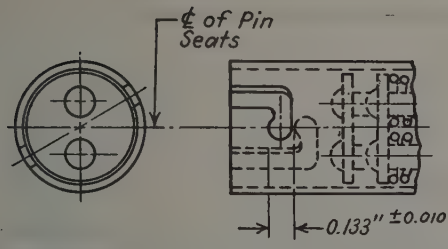

FIG. 8—D-C BAYONET SOCKET, CLOSED-IN TYPE, INDEXING

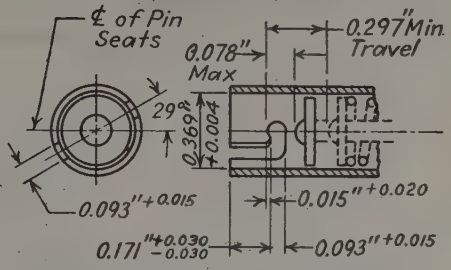

FIG. 9—MINIATURE BAYONET SOCKET

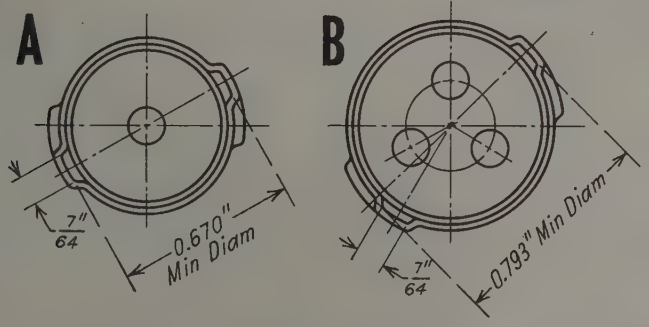

FIG. 10—EMBOSSED-TYPE BAYONET SLOTS (Figs. 10A, 10B, and 10C pertain to Figs. 1, 6, and 9, respectively.)

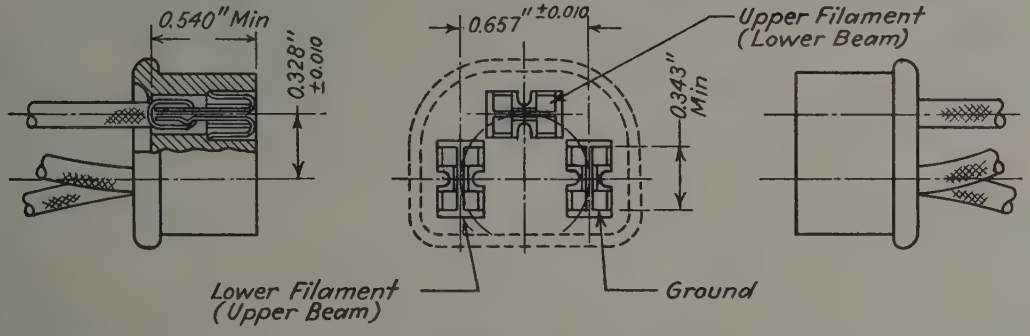

FIG. 11—SEALED-BEAM CONNECTOR

Sockets Receiving Prefocus-Base Lamps

SAE Standard

Report of Lighting Technical Committee approved January 1951.

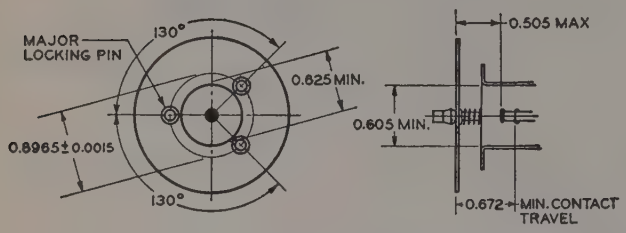

FIG. 1—PREFOCUS SOCKET FOR TYPE E-1 BASE

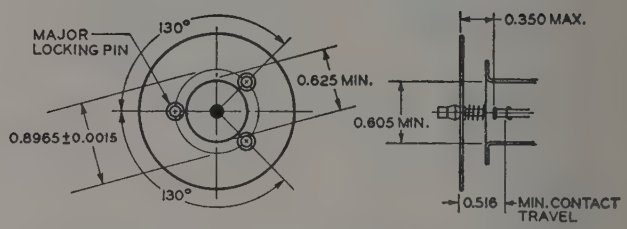

FIG. 2—PREFOCUS SOCKET FOR TYPE F-1 BASE

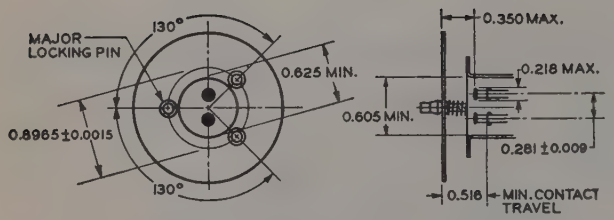

FIG. 3—PREFOCUS SOCKET FOR TYPE F-2 BASE

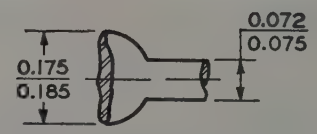

FIG. 4—DETAIL OF LOCKING PIN

Electric Fuses

SAE Standard

Report of Electrical Equipment Division approved January 1914 and last revised by Electrical Equipment Technical Committee March 1950

General Data—These fuses are intended primarily for automotive wire protection. They are not intended for apparatus protection. Automobile-radio manufacturers generally insist on more rigid specifications to insure satisfactory protection.

The length of contact surfaces specified are to insure sufficient contact for the fuses to operate properly. The fuse tube shall be of clear glass permitting the fuse strip to be seen readily.

The minimum length of fuse shall be the distance from the ends of the contact surface of the caps, and the maximum length shall be the distance overall. Caps shall be of nickel or cadmium plated brass or copper, they shall be tightly attached to the glass tube, and the ends shall be square and free of solder.

The completed fuse shall be capable of being passed through a tubular gage as long as the fuse itself and having a uniform hole of 0.258 in. diameter. Table 1 and Fig. 1 give fuse capacities and dimensions.

Rating—The rated ampere capacity of each fuse shall be marked on one of the caps. A fuse of any other than the standard ampere rating shall be of the same dimensions as for the fuse of the next larger standard size. Fuses will be rated at 32 v.

Tests—All fuses shall carry 100% of their rated current continuously and shall blow at 125% load in less than 1 hr, and within 25 sec at 200% of rated load. The test shall be made in an ambient temperature of 65 to 90 F (18 to 32 C). The test is to be made with fuses in the horizontal position. Fuses tested at rated current may be used for the overload test.

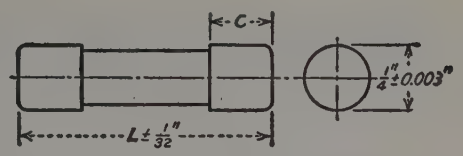

FIG. 1—FUSE DIMENSIONS

TABLE 1—*Fuse Capacities and Dimensions*

SAE CAPACITY, AMP	NOMINAL LENGTH, *L*, IN.	MINIMUM *C*, IN.	MINIMUM CAP THICKNESS, *T*, IN.
4	5/8	1/4	0.008
6	3/4	1/4	0.008
9	7/8	1/4	0.008
14	1 1/16	1/4	0.008
20	1 1/4	1/4	0.008
30	1 7/16	3/8	0.015

Voltages for Diesel Electrical Systems

SAE Recommended Practice

Report of Electrical Equipment Division approved January 1939 and last revised January 1945.

[*This SAE Recommended Practice is intended to apply to lamps, batteries, heaters, radios, and similar equipment for operation with mobile or automotive diesel engines. Twenty-four volt systems have long been used for heavy-duty services because 24 v permits operating 12-v systems in series-parallel. Thirty-two volt systems have been used for marine, railroad-car lighting, and other uses.*]

Generators, storage batteries, starting motors, lighting, and auxiliary electrical equipment shall be for nominal system ratings of 12, 24, or 32 v as determined by the power requirements of the application. It is recommended that no intermediate voltages be considered except that a 30-v system may be used when cranking requirements permit and no lighting or auxiliary electrical equipment is involved.

The combination of a 24-v starting motor and two 12-v batteries connected in series for cranking and reconnected in parallel for charging from a 12-v generator and for operating lights and other auxiliary equipment is considered practical where it can be adapted to the installation.

Storage Batteries

SAE Standard

Report of Electrical Equipment Division approved January 1914 and last revised by Electrical Equipment Technical Committee June 1949.

[*The specifications in this Standard apply to types of batteries used in motorboats, motor vehicles, tractors, and automotive industrial applications for 6- and 12-v electrical requirements. Multiple units of these types may readily be used for higher voltage requirements.*

Supplementary notes describing two types of equipment for conducting life tests, materials required, and general directions for assembling the life-test equipment may be found in the 1947 SAE Handbook and earlier editions.]

Application—This Standard is intended to apply only to lead-acid storage batteries for automotive purposes.

Testing Procedure—Capacity ratings are to be determined by the procedures outlined under Sampling, Conditioning, and Sequence of Tests. Battery classifications, ratings, and dimensions are given in Table 1.

Sampling—Five batteries shall be selected as a sample for tests. The age of the sample from date of manufacture shall be not less than ten nor more than sixty days.

Conditioning—*Charging Rate*—The battery shall be charged at the 20-hr rate until the charge voltage and specific gravity, corrected for temperature, are constant over three successive readings taken at 1-hr intervals.

Electrolyte Temperature—During the period of charging, the electrolyte temperature shall be maintained between 60 and 110 F.

Specific Gravity—The fully charged specific gravity of the electrolyte shall be 1.280 to 1.300 at 80 F, and the electrolyte level shall be not less than 3/8 in. over the top of the separators unless otherwise specified by the manufacturer.

Sequence of Tests

1. Charge battery according to the methods given under Conditioning before each discharge.
2. Discharge at the 20-hr rate to an end terminal voltage equivalent to 1.75 v per cell.
3. Discharge at 300 amp at 0 F to a terminal voltage equivalent to 1 v per cell. Record voltage at 5 sec (30 sec for Group D batteries) and discharge time in minutes to end terminal voltage.
4. Repeat Step 2.
5. Repeat Step 4.
6. Perform life tests.

The highest values obtained in this sequence shall be accepted as the performance of that battery. Batteries which test less than 95% of any rating claimed will be examined for mechanical defects, and if such a defect is present the test data will be disregarded and another sample battery taken.

Ratings—Batteries for combined starting and lighting service shall meet the ratings shown in Table 1. The 20-hr rating indicates the parking-lamp load of automotive-type batteries. The final terminal voltage for the above discharge shall be equivalent to 1.75 v per cell at 80 F. The temperature of the battery at the beginning of such discharge shall be 80 F, and an average temperature of 80 F shall be maintained during discharge with a maximum variation of plus or minus 5 F.

The second rating shall indicate the cranking ability of the battery at low temperature and shall be: (a) the time in minutes when the battery is discharged continuously at 300 amp to a final terminal voltage equivalent to 1 v per cell, the temperature of the battery electrolyte at the beginning of such discharge being 0 F; and (b) the terminal battery voltage at 5 sec for automotive types or at 30 sec for diesel types. This discharge at 300 amp shall be made after standing in a fully charged state in an atmosphere of 0 ± 1 F for not less than 24 hr.

Cycling Life Test—Batteries of all sizes shall be discharged for 1 hr at approximately 40 amp for a total of 40 amp-hr and recharged at the rate of approximately 10 amp for 5 hr for a total of 50 amp-hr. The total time for one complete cycle is 6 hr, which permits 4 cycles per day or approximately 27 cycles a week. The average temperature of the electrolyte of the center cell shall be maintained at 110 ± 5 F during the life cycles. In order to determine the condition of the battery throughout the duration of this life test, one complete capacity discharge test is made each week at 40 amp. The length of time in hours required for the battery voltage to drop to a final terminal voltage equivalent at 1.70 v per cell while discharging at 40 amp, multiplied by 40, gives the ampere-hour capacity of the battery at this rate.

When the capacity of the battery on a complete capacity discharge cycle, at the 40-amp rate, drops below the ampere-hours equivalent to 40% of the ampere-hours rated by the manufacturer at the 20-hr rate, the life test of the battery shall be considered completed. The point of failure shall be determined by plotting the ampere-hour discharge capacities. If a check is desired on the ability of the battery to maintain its cranking ability at low temperature during the cycle life testing, discharges shall be according to Step 3 of the Sequence of Tests at two, five, eight, and each three weeks thereafter until the end of cycle life testing. The complete capacity discharge test is omitted in the week of the cold-cycle test and each cold test is counted as a life cycle. Recharge after 300 amp discharge shall be 7.5 amp for a period equal to 1 hr for each minute discharge at 300 amp.

A complete capacity discharge cycle should not be made after the battery has stood on open circuit without a freshening charge of 1 hr at 10 amp for every 24 hr on open circuit.

Water should be added as required, except that no water should be added just before the complete capacity discharge cycle.

Overcharge Life Test—This test was designed to provide more overcharge than that covered in the cycling life test. A charge of 990 amp-hr is given, followed by a discharge capacity check, thereby representing one week's testing on a continuous basis or one complete life unit. The procedure for a life unit is as follows:

(a) 990 amp-hr of continuous charge is given at 9 amp, regardless of battery size, with batteries in a water bath as specified in (b).

(b) The battery is given a 48-hr stand on open circuit in a water bath.

(c) A 300-amp discharge check rate is given at the battery temperature obtained in (b) to an end voltage equivalent to 1.20 v per cell or a minimum discharge time of 30 sec, whichever occurs first.

(d) Repeat (a) to (c) without separate discharge.

(e) The overcharge life test shall be considered completed

TABLE 1—*Battery Classifications, Ratings, and Dimensions*

Recommended Service	SAE No.	Assembly		Battery Volts	Maximum Overall Dimensions[a], In.			Minimum Electrical Values				
		Type	Fig. no.		Length, *L*	Width, *W*	Height, *H*	Ampere-hour capacity at 20-hr rate	300 amp at 0 F: Minutes to 1 v per cell	300 amp at 0 F: 5 sec volts	Life cycles, minutes	Tentative min overcharge life units
With gasoline engines	1M	Standard	1	6	9⅛	7⅛	9⅛	90	3.0	4.0	250	4
	1H	Standard	1	6	9⅛	7⅛	9⅜	100	3.5	4.1	275	5
	2M	Standard	1	6	10⅜	7⅛	9⅛	110	4.0	4.2	300	6
	2H	Standard	1	6	10⅜	7⅛	9⅜	120	4.5	4.3	325	7
	2L	Reverse	3	6	10⅝	7 5/16	8⅛	100	3.5	4.1	275	5
	2E	Long	2	6	19⅜	4⅛	9⅜	100	3.5	4.1	275	5
	2F	Reverse	3	6	10⅝	7 5/16	9⅜	120	4.5	4.3	325	7
	3H	Standard	1	6	11¾	7⅛	9⅜	130	5.0	4.4	350	7
	4H	Standard	1	6	13⅛	7⅛	9⅜	150	6.0	4.5	400	9
	7G[b]	Standard	1	6	16⅞	7⅝	10⅞	160	3.5	3.8	500	15
	4G[b]	Standard	4	12	21¼	8¾	10⅞	120	1.2	6.8	400	11
	6G[b]	Standard	4	12	21¼	10	10⅞	140	2.5	7.2	450	13
	8G[b]	Standard	4	12	21¼	11⅛	10⅞	160	3.5	7.6	500	15
										30 sec volts		
With diesel and gasoline engines	7D	Standard	1	6	16⅞	7⅝	10⅞	200	10.5	4.9	525	13
	4D	Standard	4	12	21¼	8¾	10⅞	150	6.0	9.3	400	9
	6D	Standard	4	12	21¼	10	10⅞	165	7.5	9.5	440	10
	8D	Standard	4	12	21¼	11⅛	10⅞	200	10.5	9.8	525	13

[a] Note interchangeability of case size in G and D groups.
[b] Ratings for G-type batteries are for double insulation. When double insulation is used in other types, deduct 10% from the time and voltage ratings at 300 amp at 0 F and add 15% to the SAE cycling life.

when the battery fails to meet (c). The battery shall meet the minimum life units (weeks) specified in Table 1. The number of life units (weeks) on test shall be computed to the last week in which the minimum time of 30 sec has been equalled or exceeded; that is, the week in which the battery failed shall not be counted in reporting the life units.

(f) Water shall be added daily during charge to restore electrolyte level to normal.

Test Equipment and Specifications—*Tank*—The tank shall be a lead-lined metal tank, 10 in. inside depth. The immersion of batteries shall be to a 6-in. depth. The battery supports are to be two wooden strips 1 in. high and 1½ in. wide, running the length of the tank, and so spaced that they will insulate the battery from the bottom of the tank. The tank shall be of sufficient size to permit a minimum of 1-in. battery clearance on all sides. Means shall also be provided for thermostatically controlling water temperature at 100 ± 5 F.

Electrical Equipment—This may be as desired to provide 9 amp direct current for charge and 300 amp direct current for discharge.

Double Insulated Batteries—Double insulation is defined for the purpose of this Standard as the use of a retaining sheet of porous or perforated material between the positive plate and the customary single separator.

Location of Battery Parts—The location and polarity of the terminal posts and the position of handles, when used, shall be as shown in Figs. 1 to 4.

Type Designations and Markings—Type letters, number, or symbols, which shall enable the user to determine ratings from the manufacturer's catalogs, shall be stamped or molded on the

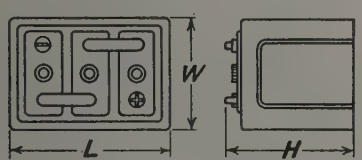

Fig. 1—Standard Assembly

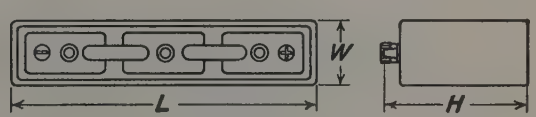

Fig. 2—Long Assembly

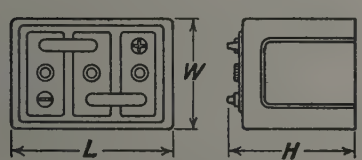

Fig. 3—Reverse Assembly

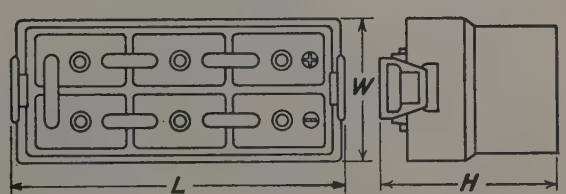

Fig. 4—Motorcoach Assembly

case or cell connectors or on a name plate permanently attached to the end or side of the battery, or the ampere-hour capacity at the 20-hr rate shall be molded on the side or end of the container.

Grounding—The storage battery should be securely and adequately grounded. All contact surfaces in the grounding circuit should be clean, tinned, and free from oxide or paint. The ground connection from the battery should be readily accessible for servicing.

Terminal Posts—Polarity shall be plainly marked as follows: The positive post shall be marked Pos or P or +. When taper posts are used for terminals of lead-acid storage batteries, the dimensions in inches shall be as follows:

Small diameter of negative post	5/8 in.
Small diameter of positive post	11/16 in.
Minimum length of taper	5/8 in.
Taper per foot, included angle	1⅓ in.

Starting-Motor Circuits

SAE Standard

Report of Electrical Equipment Division approved January 1932.

The starting-motor circuits in motor vehicles shall be designed so that the difference between the voltage at the storage-battery terminals and the voltage at the starting-motor terminals shall not exceed 0.12 v per 100 amp, with the circuit at a normal temperature of 68 F.

Starting Motors

SAE Standard

Report of Electrical Equipment Division approved August 1917 and last revised January 1945.

Mountings may be used for either right-hand or left-hand applications.

Outboard Installations—When teeth are cut in the flywheel, the full depth of hobbing should be 7/8 in. If a steel ring gear less than 7/8 in. wide is used, a clearance should be provided to a depth of 7/8 in. for the pinion mesh.

Terminal-Post Sizes for Starters and Starter Switches—The threads on terminal posts shall be as follows:

For light duty	5/16"—18NC—2
For medium and heavy duty	3/8" —16NC—2
For extra-heavy duty	1/2" —13NC—2

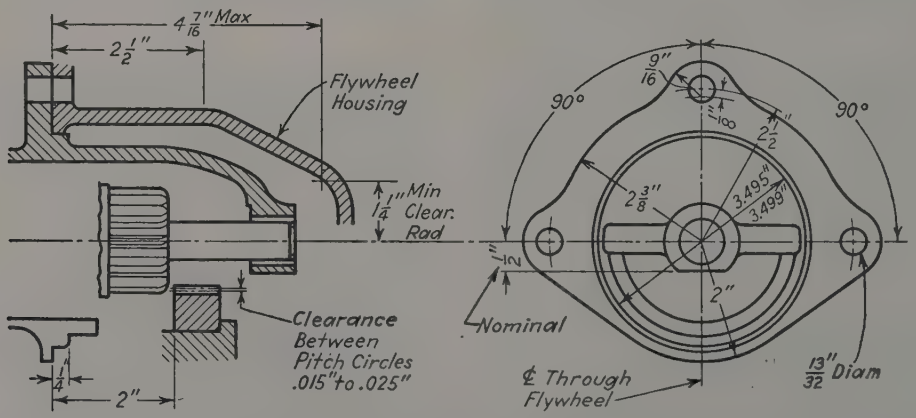

FIG. 1—3-BOLT FLANGE MOUNTING, OUTBOARD TYPE, NO. 1 FLANGE, MEDIUM DUTY

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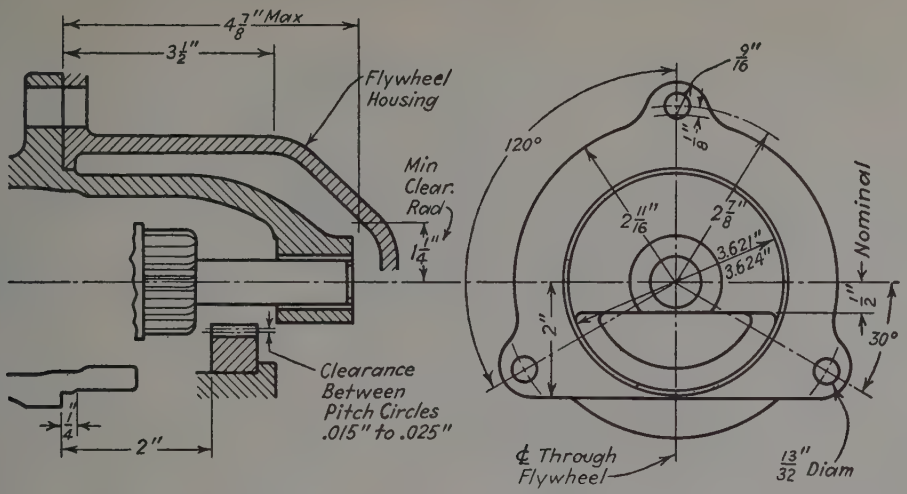

FIG. 2—3-BOLT FLANGE MOUNTING, OUTBOARD TYPE, NO. 2 FLANGE, MEDIUM-HEAVY DUTY

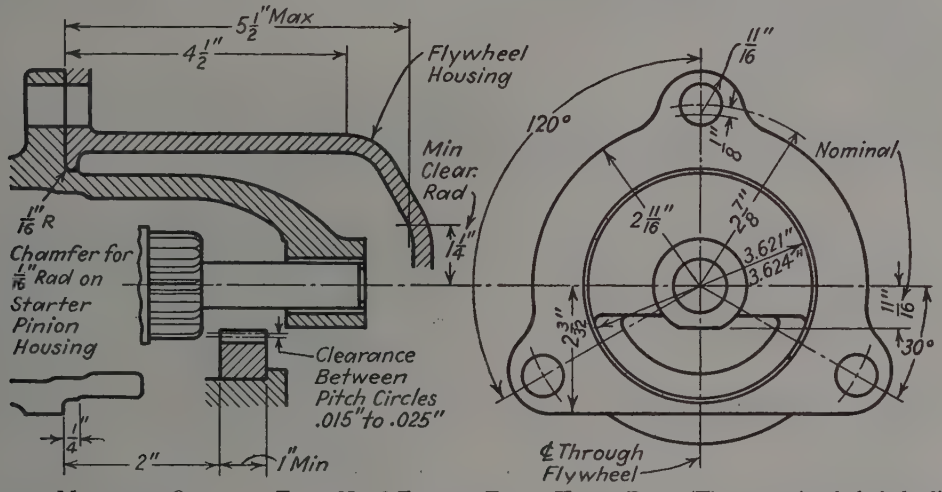

FIG. 3—3-BOLT FLANGE MOUNTING, OUTBOARD TYPE, NO. 3 FLANGE, EXTRA-HEAVY DUTY (The mounting bolt-hole diameters may be 17/32 or 21/32 in.)

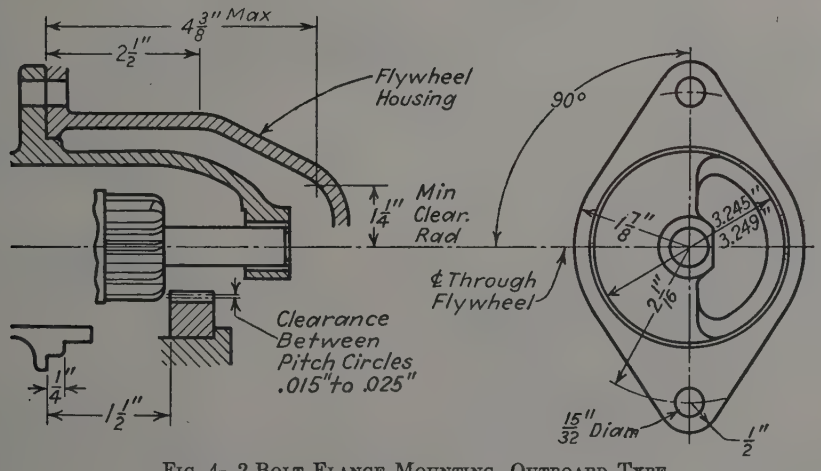

FIG. 4—2-BOLT FLANGE MOUNTING, OUTBOARD TYPE

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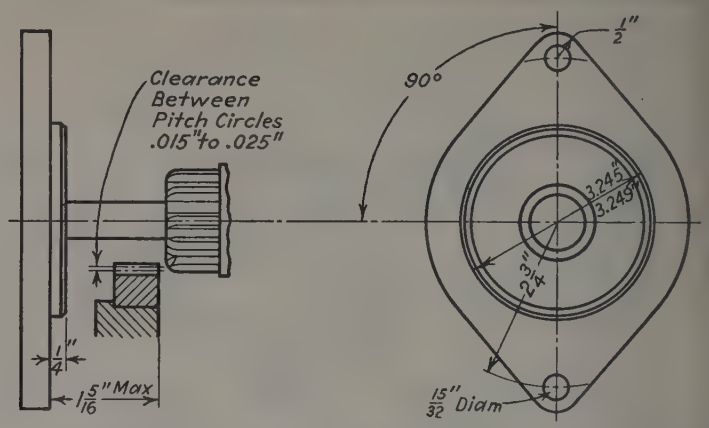

FIG. 5—2-BOLT FLANGE MOUNTING, INBOARD TYPE

Starter Pinions and Ring Gears

SAE Recommended Practice

Report of Electrical Equipment Division approved August 1917 and last revised January 1945.

Fig. 1 illustrates and shows dimensions of starter ring gears and pinion. Table 1 gives dimensions and uses of starting-motor pinions.

Ring-Gear Hardness—*Light and Medium Duty*—Hardness for carbon-steel ring gears is to be Rockwell C42 to C49 after assembly with flywheel.

Heavy Duty—Hardness for case-hardened steel ring gears is to be Rockwell C48 to C52 after assembly with flywheel.

Extremely Heavy Duty—Hardness up to Rockwell C60 may be desirable after assembly with flywheel.

TABLE 1—*Starting-Motor Pinions*

NO. OF TEETH	PITCH	OUTSIDE DIAM	PITCH DIAM[a]	ROOT DIAM	PRESSURE ANGLE, DEG	TOOTH DEPTH	USE
9[b]	10/12	1.167	1.000	0.787	20	0.190	Light duty
9[b]	10/11	1.204	1.000	0.812	14½	0.196	Light duty
11 or 10[c]	8/10	1.575	1.375	1.143	20	0.216	Light duty
13	8/10	1.825	1.625	1.393	20	0.216	Medium duty
12 or 11[d]	6/8	2.250	2.000	1.710	20	0.270	Heavy duty

[a] Pitch diameter is for layout purposes.
[b] This is 9-tooth pinion cut on standard 10-tooth blank.
[c] This is 10-tooth pinion cut on standard 11-tooth blank.
[d] This is 11-tooth pinion cut on standard 12-tooth blank.

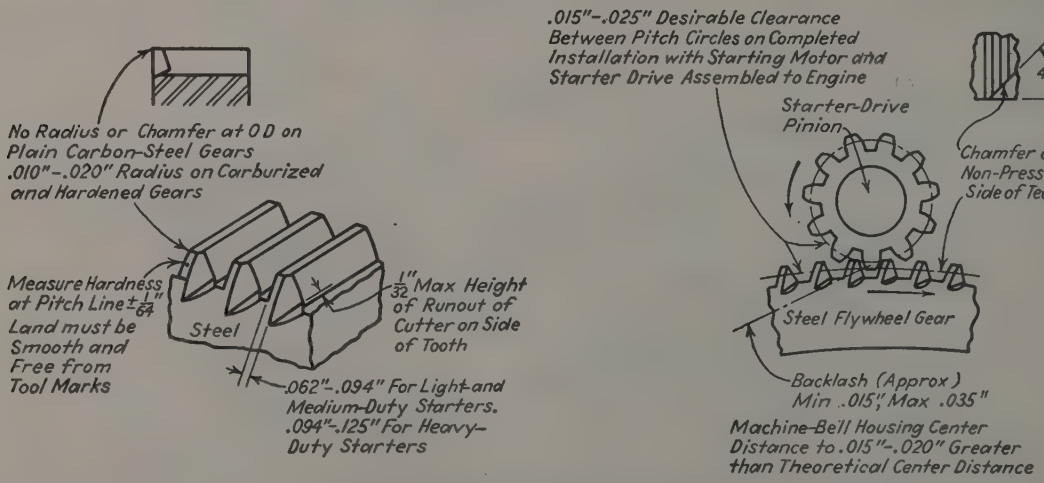
No Radius or Chamfer at O D on Plain Carbon-Steel Gears .010"-.020" Radius on Carburized and Hardened Gears
Measure Hardness at Pitch Line ± 1/64"
Land must be Smooth and Free from Tool Marks
Steel
1/32" Max Height of Runout of Cutter on Side of Tooth
.062"-.094" For Light and Medium-Duty Starters. .094"-.125" For Heavy-Duty Starters
.015"-.025" Desirable Clearance Between Pitch Circles on Completed Installation with Starting Motor and Starter Drive Assembled to Engine
Starter-Drive Pinion
45°
Chamfer on Non-Pressure Side of Teeth
Steel Flywheel Gear
Backlash (Approx) Min .015", Max .035"
Machine-Bell Housing Center Distance to .015"-.020" Greater than Theoretical Center Distance

FIG. 1—STARTER RING GEARS AND PINION

Starting-Motor and Generator Curves

SAE Recommended Practice

Report of Electrical Equipment Division approved January 1945.

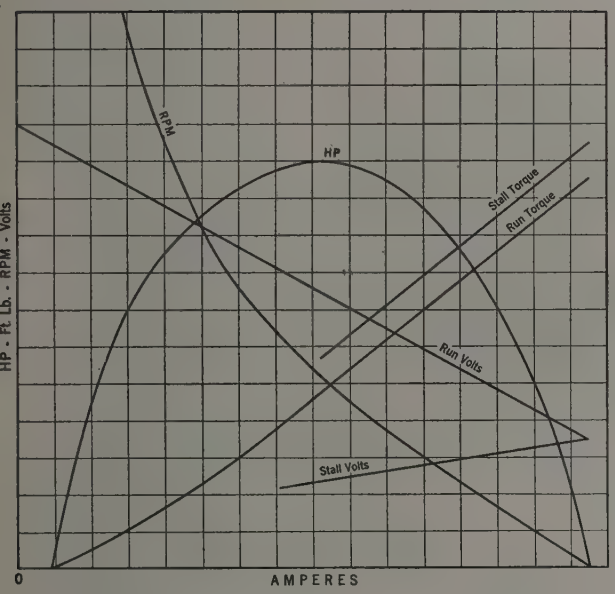

FIG. 2—STANDARD FORM FOR STARTING-MOTOR CHARACTERISTIC CURVES

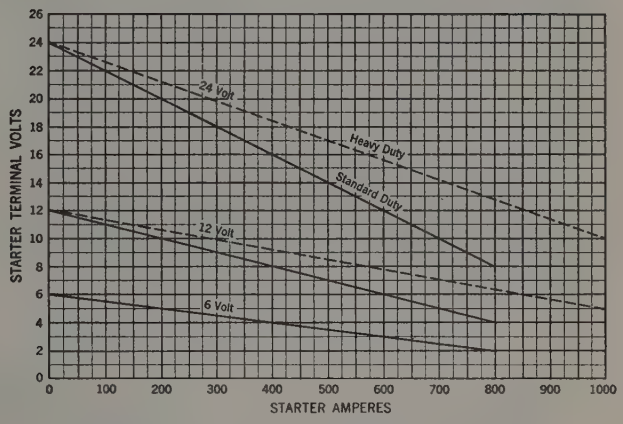

FIG. 1—VOLTAGE CURVES FOR STARTER TESTS

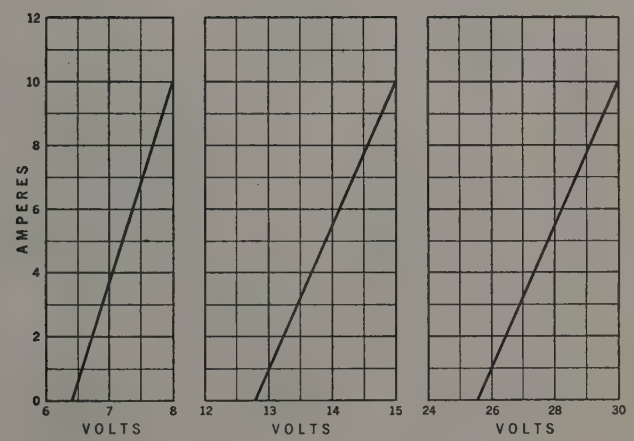

FIG. 3—GENERATOR TEST CURVES

The maximum voltages of 8, 15, or 30 should be used in calculating wattage ratings of generators. Voltages shall remain constant above 10 amp.

Generator Mountings

SAE Standard

Report of Electrical Equipment Division approved August 1917 and last revised January 1945.

Fig. 1 shows a flange-type generator. The flange mounting shall be provided with a pilot when used with a gear drive and with slotted holes to allow for adjustment when used with a chain drive. In the latter case, the hole in the gearcase should clear the pilot.

Fig. 2 shows a cradle-mounted type generator. If a ventilating fan is required, consult manufacturer for integral fan and pulley dimensions.

Fig. 3 shows a base-mounted type generator in the small size. This generator shaft end is suitable for all sizes of generator except in special instances where small generators, naturally not suited to this Standard, may be fitted with the SAE Standard magneto shaft end.

Fig. 4 shows a base-mounted type generator with large diameter. If a ventilating fan is required, consult manufacturer for integral fan and pulley dimensions.

Figs. 5, 6, and 7 show hinge-mounted type generators. If a ventilating fan is required, consult manufacturer for integral fan and pulley dimensions.

Generator Terminal Posts—Field terminal-post threads shall be No. 10—32 NF—2 minimum. Armature terminal-post threads shall be $\frac{5}{16}$"—18 NC—2 (except for generator in Fig. 5). Terminal posts may be located radially or longitudinally on the generator frame.

Tables 1a and 1b give dimensions for generators and for armature terminal-post threads.

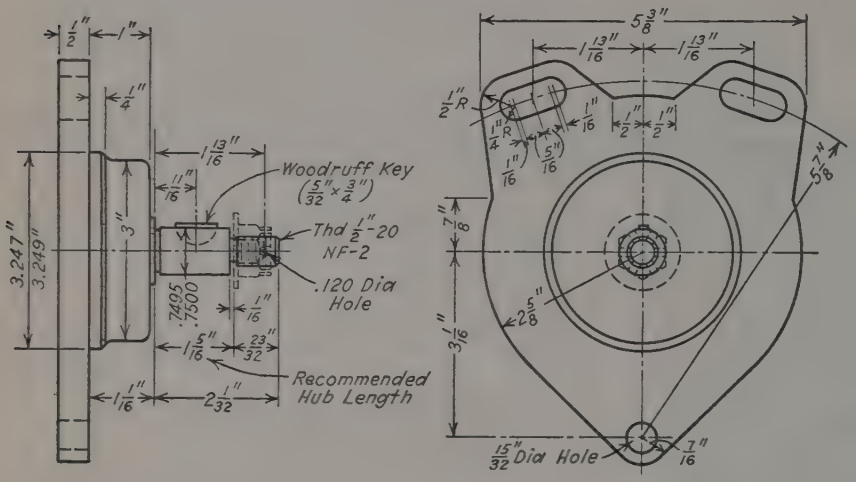

Fig. 1—Flange Type

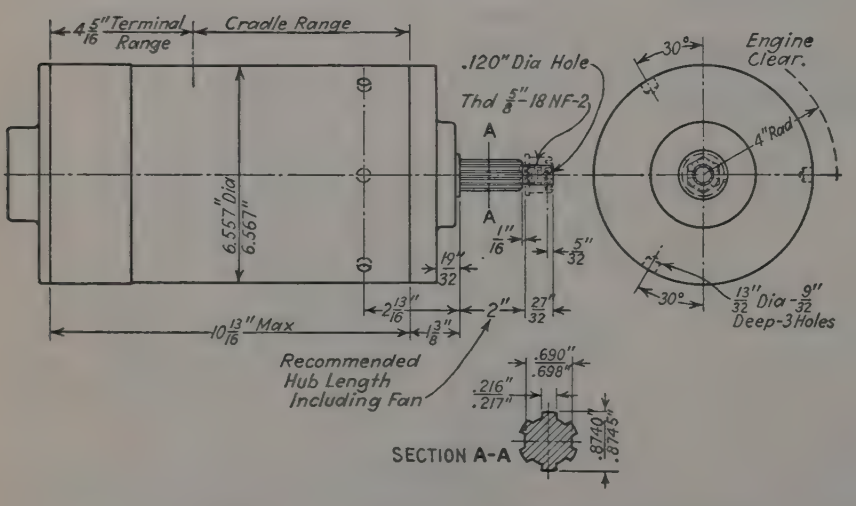

Fig. 2—Cradle-Mounted Type

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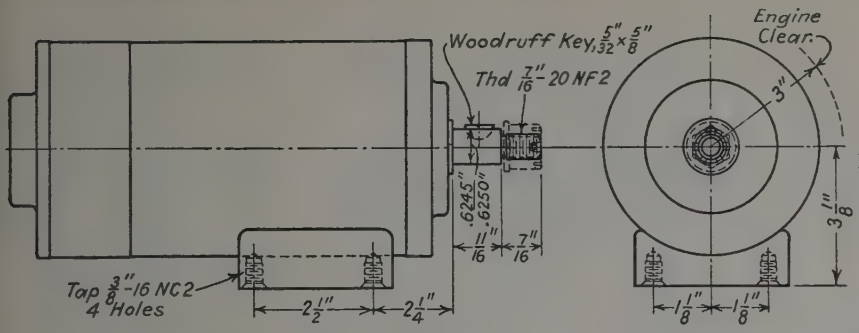

FIG. 3—BASE-MOUNTED TYPE, SMALL SIZE

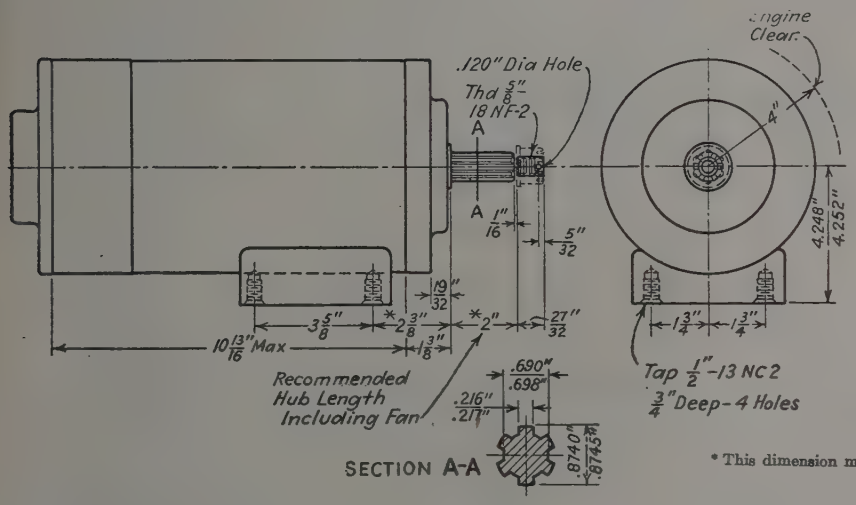

FIG. 4—BASE-MOUNTED TYPE, LARGE DIAMETER

* This dimension may be changed if required by application.

(For Fig. 5, see next page.)

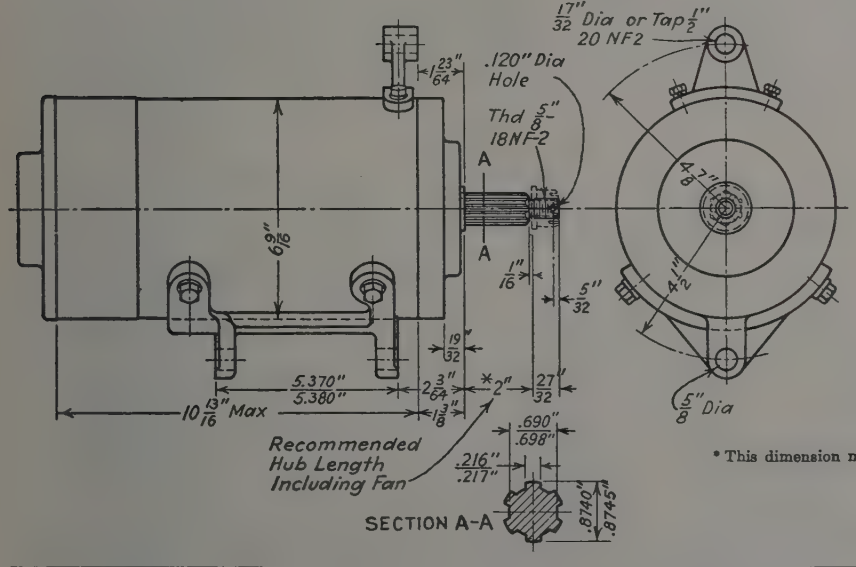

FIG. 6—HINGE-MOUNTED TYPE

* This dimension may be changed if required by application.

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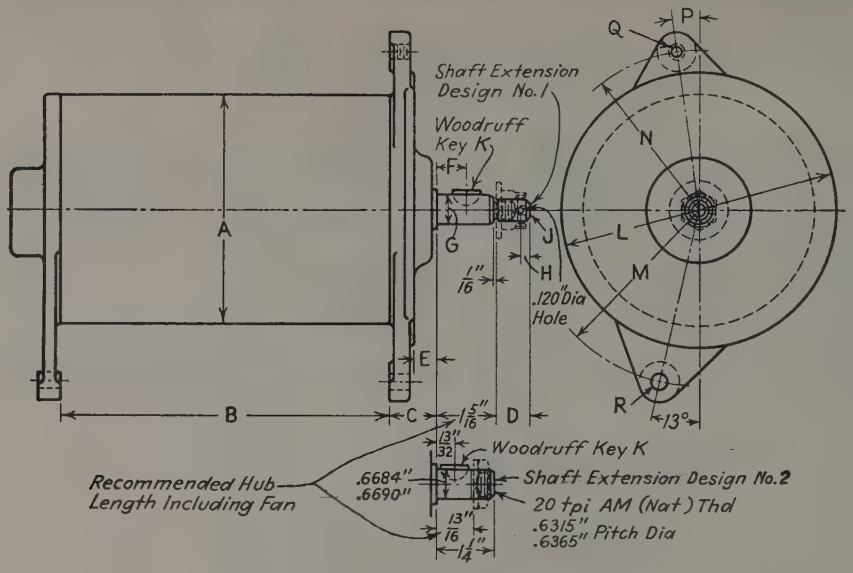


FIG. 5—HINGE-MOUNTED TYPE

TABLE 1a—*Generator Dimensions and Armature Terminal Posts*

GENERATOR DIAM, *A*	*B*, MAX	*C*	*D*	*E*	*F*	*G*	*H*	THREADS, *J*	KEY, *K*	*L*, MAX
4 9/16	7 1/4	1	2 3/32	0.500 0.536	2 1/32	0.6684 0.6690	3/16	1/2"–20 NF-2	1/8 × 5/8	5 1/16
5 1/16	7 1/4	1	2 3/32	0.500 0.536	2 1/32	0.6684 0.6690	3/16	1/2"–20 NF-2	1/8 × 5/8	6 1/16
[a] 5 9/16	9 11/32	1 3/16	2 7/32	0.549 0.568	4 5/64	0.8740 0.8745	5/32	5/8"–18 NF-2	5/32 × 3/4	6 1/2
[a] 5 9/16	9 11/32	0.950 0.976	2 5/32	0.300 0.346	5/8	0.7495 0.7500	5/32	1/2"–20 NF-2	5/32 × 3/4	6 1/2

[a] The hub length may be reduced on 5 9/16-in. diameter generators.

TABLE 1b—*Generator Dimensions and Armature Terminal Posts*

GENERATOR DIAM, *A*	*M*	*N*	*P*, DEG	THREADS, *Q*	DIAMETER, *R*	SHAFT EXTENSION	ARM. TERM. POST, MIN
4 9/16	3 1/16	2 15/16 or 3 1/16	3 or 42	5/16"–18 NC-2	2 1/64	Design 1 or 2	No. 12–24 NC-2
5 1/16	3 7/8 Max	3 1/2 Max	8	5/16"–18 NC-2	2 1/64 or 2 9/64	Design 1 or 2	No. 12–24 NC-2
[a] 5 9/16	3 7/8	3 7/8	8	3/8"–16 NC-2	2 9/64	Design 1	1/4"–20 NC-2
[a] 5 9/16	3 7/8	3 7/8	8	3/8"–16 NC-2	2 9/64	Design 1	1/4"–20 NC-2

[a] The hub length may be reduced on 5 9/16-in. diameter generators.

(*Continued on next page.*)

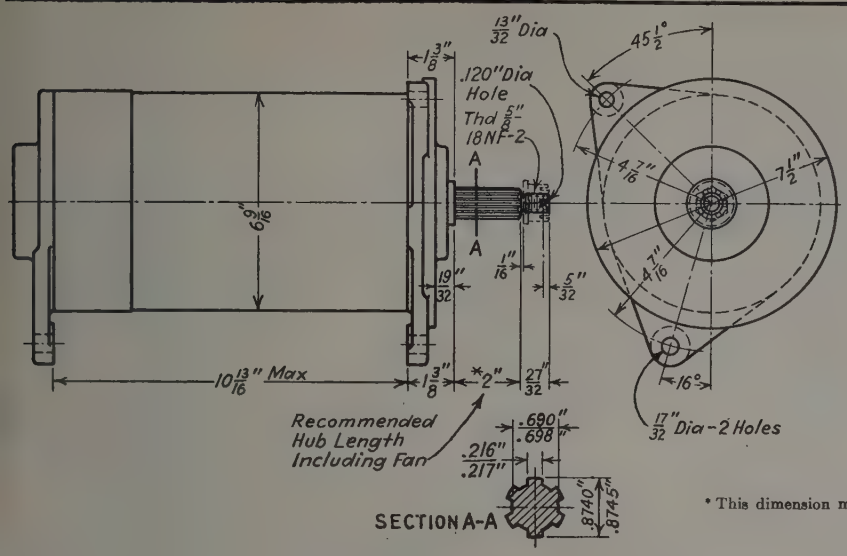


FIG. 7—HINGE-MOUNTED TYPE

* This dimension may be changed if required by application.

Magneto Mountings

SAE Standard

Report of Miscellaneous and Electrical Equipment Divisions approved January 1913 and last revised by Tractor and Equipment Division January 1941.

[*For vertical-type magneto mountings, see SAE Standard for Distributor and Vertical Magneto Mountings. For aircraft magneto mountings, see SAE Aeronautical Standards AS 12 and AS 13.*]

General-Purpose Magneto Mountings—Fig. 1, Fig. 2, and Table 1 give dimensions for magneto couplings and shaft ends. Fig. 2 and Table 2 give magneto-mounting dimensions.

Magneto Couplings—Magneto couplings shall be 2⅜ in. long and shall have a maximum outside diameter of 3¼ in.

Nonmagnetic Magneto Shims—When it is desired to use a nonmagnetic shim with magnetos mounted on cast-iron pads, the shims shall be ½ in. thick, and high-strength bronze bolts shall be used. The thickness of the shims shall be added to the dimension *G* when laying out the distance from the face of the mounting

pad to the center of the magneto shaft. A grid construction for the shims is considered preferable.

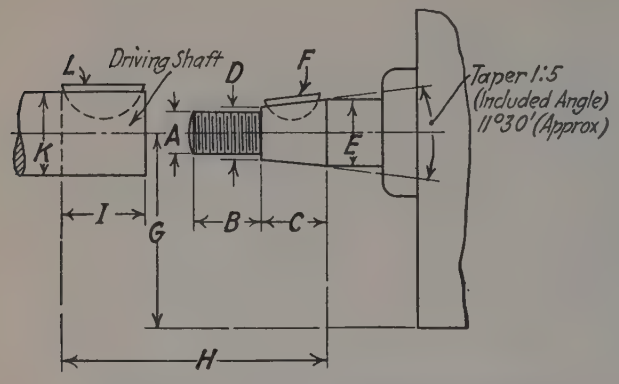


FIG. 1—MAGNETO-COUPLING AND SHAFT-END DIMENSIONS

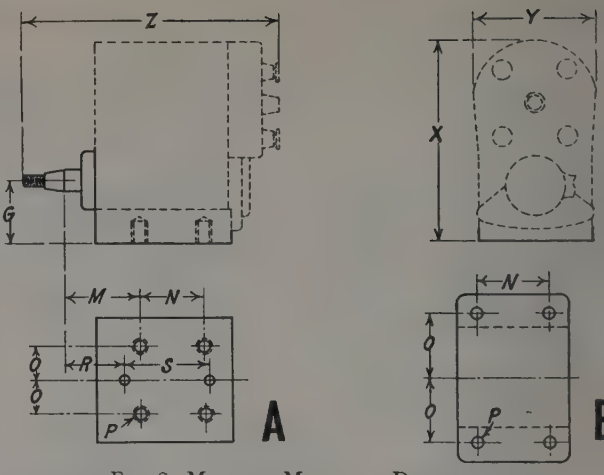


FIG. 2—MAGNETO-MOUNTING DIMENSIONS
A—BASE MOUNTING B—FLANGE MOUNTING

TABLE 1—*Magneto-Coupling and Shaft-End Dimensions*

TYPE		SAE COARSE THREADS, *A*	*B*	*C*	*D*	*E*	WOODRUFF KEY, *F*	*G*	*H*, MAX	*I*	*K*	COUPLING-BORE LIMITS	WOODRUFF KEY NO. 8
All service (1, 2, 4, and 6 cylinder)	In.	3/8–16	0.591	0.591	0.472	0.591	1/2x1/8	1.772	2.375	0.750	0.7500 0.7490	0.7505 0.7495	3/4x5/32
	Mm	9.53–1.58	15.00	15.00	12.00	15.00	—	45.00	60.32	19.05	19.050 19.025	19.063 19.037	—
Motorcycle and lighting plant	In.	5/16–18	0.438	0.354	0.441	0.512	5/16x3/32	1.772	—	—	—	—	—
	Mm	7.94–1.41	11.11	9.00	11.20	13.00	—	45.00	—	—	—	—	—
Small stationary engine, base mounting	In.	5/16–18	0.438	0.354	0.441	0.512	5/16x3/32	1.378	—	—	—	—	—
	Mm	7.94–1.41	11.11	9.00	11.20	13.00	—	35.00	—	—	—	—	—
Small stationary engine, flange mounting	In.	5/16–18	0.438	0.354	0.441	0.512	5/16x3/32	1.378	—	—	—	—	—
	Mm	7.94–1.41	11.11	9.00	11.20	13.00	—	35.00	—	—	—	—	—

TABLE 2—*Magneto-Mounting Dimensions*[a]

TYPE		*M*	*N*	*O*	SAE COARSE THREADS, *P*	ADVANCE LEVER RADIUS	TIMING-LEVER HOLES		MAXIMUM MAGNETO SPACE[b]		
							Tapped	Plain	*X*	*Y*	*Z*
All service (1, 2, 4, and 6 cylinder). Fig. 2A	In.	2.086	1.968	0.984	3/8–16	2.125	1/4–28	0.25	8	5	10
	Mm	53.00	50.00	25.00	9.53–1.58	53.98	6.35–0.9	6.35	203	127	254
Motorcycle and lighting plant. Fig. 2A	In.	1.555	1.968	0.984	3/8–16	1.968	—	0.219	6	3 3/4	6 3/8
	Mm	39.50	50.00	25.00	9.53–1.58	50.00	—	5.55	152	95	162
Small stationary engine, base mounting. Fig. 2A	In.	1.555	1.653	1.102	3/8–16	1.968	—	0.219	—	—	—
	Mm	39.50	41.99	27.99	9.53–1.58	50.00	—	5.55	—	—	—
Small stationary engine, flange mounting. Fig. 2B	In.	1.404	1.875	1.687	7/32	1.968	—	0.219	—	—	—
	Mm	35.65	47.61	42.85	5.55	50.00	—	5.55	—	—	—

[a] Dowel-pin hole dimensions, *R* and *S* (Fig. 2), are not given in this Standard.
[b] *X*, *Y*, and *Z* are envelope dimensions.

(*Continued on next page.*)

Flange Type for Tractors—The flange-type magneto mounting for use on tractors is shown in Fig. 3.

When the bolt centerline of the flange mounting is horizontal, the adjusting slot shall be to the left when facing the driven end of the magneto. (See Fig. 3.)

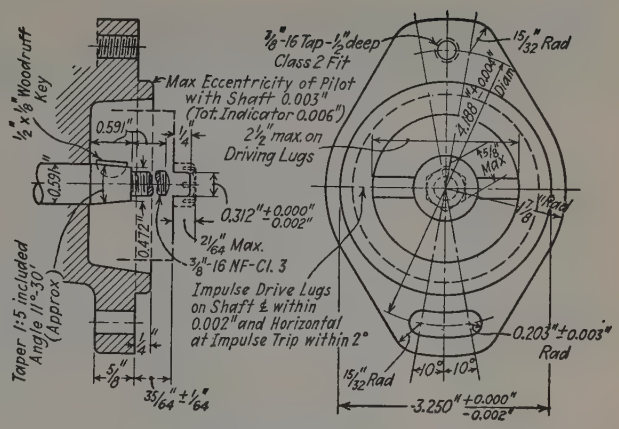

3/8"-16 Tap-1/2" deep Class 2 Fit
15/32" Rad
1/2" x 1/8" Woodruff Key
Max Eccentricity of Pilot with Shaft 0.003" (Tot. Indicator 0.006")
0.591"
2 1/2" max. on Driving Lugs
4.188" 0.004" Diam
0.594"
0.472"
0.312" +0.000" -0.002"
2 1/64" Max.
3/8"-16 NF-Cl. 3
Impulse Drive Lugs on Shaft ⊥ within 0.002" and Horizontal at Impulse Trip within 2°
Taper 1:5 included Angle 11°30' (Approx)
0.203" ±0.003" Rad
15/32" Rad
10° ±10°
3.250" +0.000" -0.002"
5/8"
35/64" ± 1/64"

FIG. 3—FLANGE-TYPE MAGNETO MOUNTING FOR TRACTORS

Distributor and Vertical Magneto Mountings

SAE Standard

Report of Electrical Equipment Division approved August 1917 and last revised January 1945.

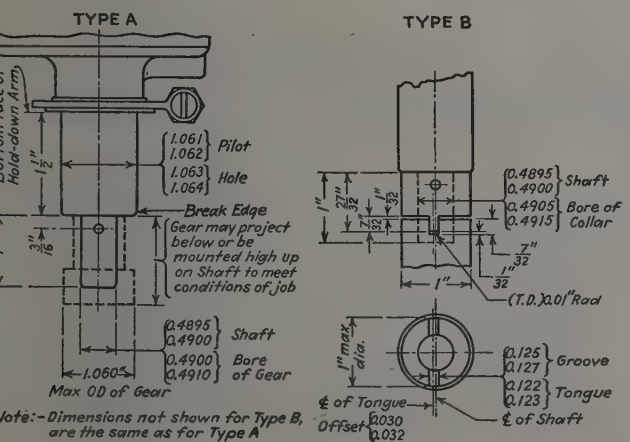

TYPE A
TYPE B
1.061 1.062 Pilot
1.063 1.064 Hole
Break Edge
Gear may project below or be mounted high up on Shaft to meet conditions of job
0.4895 0.4900 Shaft
0.4900 0.4910 Bore of Gear
1.060" Max OD of Gear
0.4895 0.4900 Shaft
0.4905 0.4915 Bore of Collar
(T.D.) X.01" Rad
1" max. dia.
0.125 0.127 Groove
0.122 0.123 Tongue
℄ of Tongue
Offset 0.030 0.032
℄ of Shaft
Note:- Dimensions not shown for Type B, are the same as for Type A

FIG. 1—STANDARD MOUNTING AND DRIVES

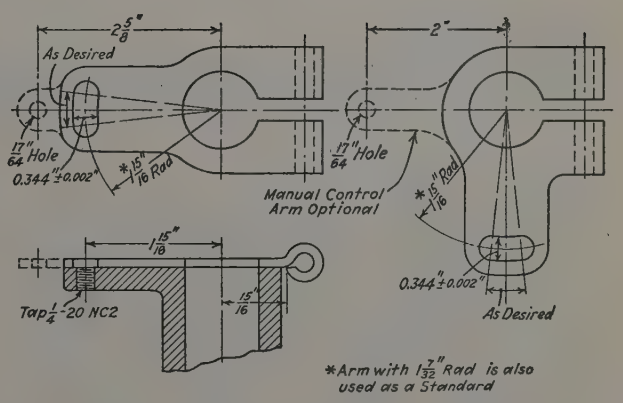


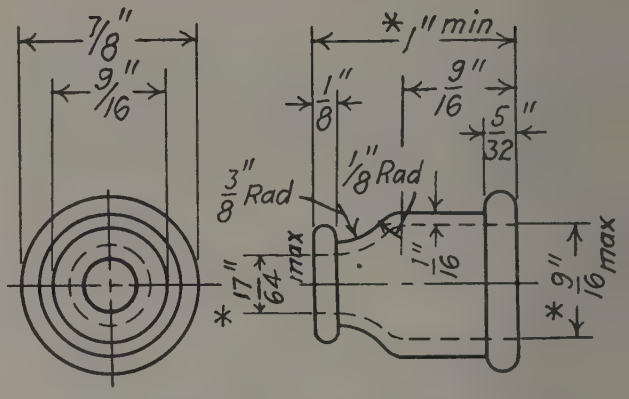
FIG. 2—DISTRIBUTOR HOLD-DOWN ARMS

7-Mm Distributor Nipple

SAE Recommended Practice

Report of Electrical Equipment Division approved June 1927 and last revised January 1945.

The materials for 7-mm distributor nipples are to be natural rubber or synthetic compounds.



* Recommended practice. Other dimensions are optional.

FIG. 1—DIMENSIONS FOR 7-MM DISTRIBUTOR NIPPLE

Spark Plugs

SAE Standard

Reports of Miscellaneous Division approved January 1915, Aircraft Division approved March 1918, Motorcycle Division approved August 1919, Electrical Equipment Division approved May 1930, and last revised by Electrical Equipment Technical Committee January 1951.

[*This SAE Standard applies only to general-automotive-type spark plugs.*

The original standard for the 7/8-in.–18 spark plug, which had a 7/8-in. hexagon, was adopted by the Mechanical Branch of the Association of Licensed Automobile Manufacturers in October 1908. This standard was taken over by the SAE in 1910. In January 1915, it was extended to include definite thread limits and the addition of the 1 1/8-in. hexagon. In March 1923, the post-, ball-, and slip-types of terminals were recommended by the Electrical Equipment Division and adopted as an SAE Recommended Practice. At that time, these terminals were commonly made in two thread sizes, No. 8–32 and 0.183–32, both of which were generally used. For this reason, the dual specification was retained until it was revised in January 1935 to include only the permanent, fixed-post type.

The motorcycle-plug threads were slightly larger than and the tapped holes slightly smaller than for the aircraft plugs; but in May 1930, all 18-mm plug threads were made the same as for the aircraft plugs.

The aircraft 18-mm spark-plug specification was separated from this general standard in January 1941 and published separately as Aeronautical Standard AS 28.]

Table 1 gives spark-plug general dimensions and Table 2 gives

dimensions for spark-plug and tapped-hole threads. See also Figs. 1–3.

Thread Gages—In order to keep the wear on threading tools within the permissible limits, the threads in the spark plug Go (ring) gage shall be truncated to the maximum minor diameter of the spark plug; and in the tapped hole Go (plug) gage, to the minimum major diameter of the tapped hole. The plain plug gage for checking the minor diameter of the tapped hole shall be the minimum specified.

Metric Conversions—The factor 1 mm = 0.03937 in. (1 in. = 25.4 mm) was used for the conversion of metric values to inch equivalents in the accompanying tables, the equivalents being figured to six decimals.

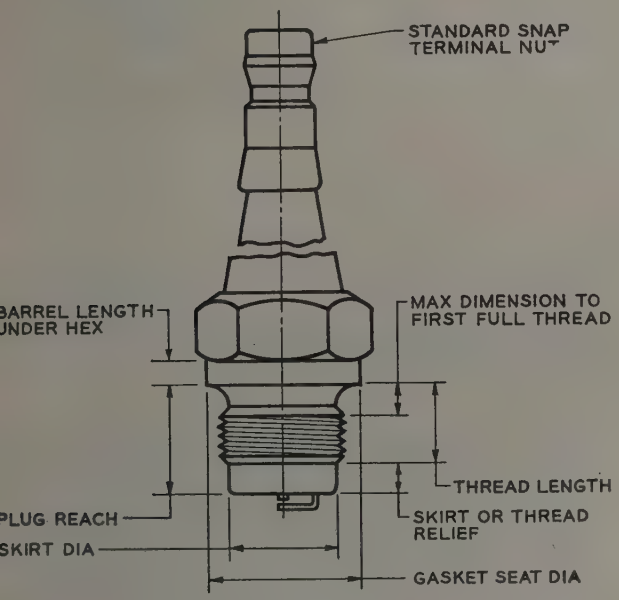


FIG. 1—SPARK PLUG

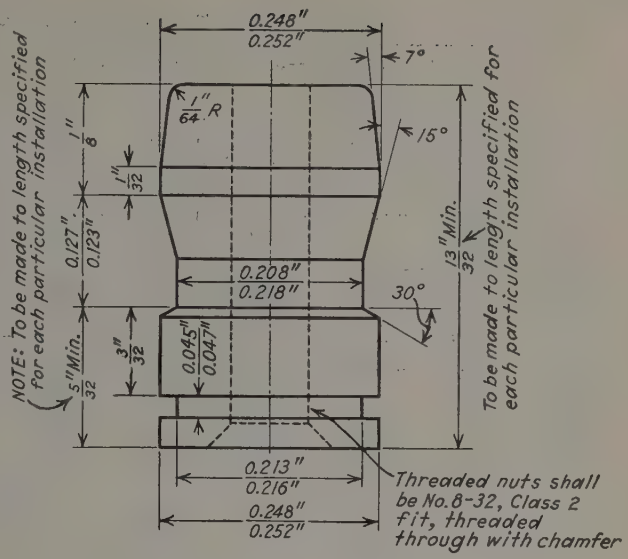


FIG. 2—SPARK-PLUG TERMINAL NUT

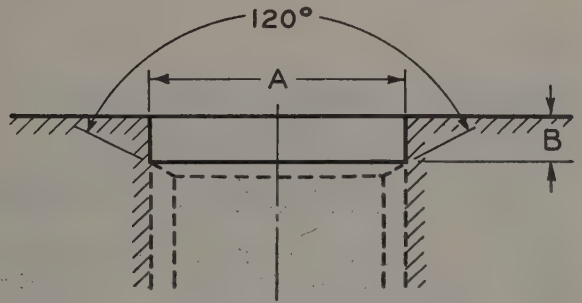


FIG. 3—HEAD COUNTERBORE

Note 1—The maximum diameter of counterbore, *A*, is 0.015 in. over the outside diameter of the plug thread

Note 2—Dimension *B* is one thread pitch

Note 3—Spark-plug threads shall not be exposed to the combustion chamber

TABLE 1—*Spark-Plug General Dimensions*

PLUG SIZES	7/8–18 (in.)	18–1.5 (mm)	14–1.25 (mm)	10–1 (mm)	3/8–24 (in.)	1/4–32 (in.)
Hexagon size, in., +0.005, −0.010 in.	15/16, 1 1/8	7/8, 1	13/16	5/8, 11/16, 9/16	1/2	3/8, 5/16, 11/32
Plug reach, in., ± 1/64 in.	1/2, 5/8	1/2, 9/16	3/8, 7/16, 1/2	1/4	7/32	7/32, 5/32
Max dimension to first full thread,[a] in.	9/64	9/64	0.130	3/64	3/64	3/64
Skirt length, in.	11/64, 25/64, 19/64, 17/64, 7/64, 5/32	7/64, 11/64, 1/8, 1/16	5/64	—	—	—
Skirt diameter, max, in.	0.789	5/8	0.480	—	—	—
Gasket seat diameter, max, in.	1 1/8	1	Hex	9/16	Hex	Hex
Barrel length under hex, min, in.	3/8	1/4	5/16	3/8	1/8	1/16

[a] Cut threads.

(*Continued on next page.*)

TABLE 2—*Spark-Plug and Tapped-Hole Threads*

SIZE		MAJOR DIAMETER		PITCH DIAMETER		MINOR DIAMETER		GO-THREAD RING GAGE, MINOR DIAMETER	GO-THREAD PLUG GAGE, MAJOR DIAMETER	PLAIN PLUG GAGE, MINOR DIAMETER, MIN
		Max	Min	Max	Min	Max	Min			
7/8–18	Plug	0.8750	0.8668	0.8384	0.8343	0.8068	—	0.8068	—	—
in.	Hole	—	0.8750	0.8430	0.8389	0.8209	0.8149	—	0.8750	0.8149
18–1.5	Plug	0.7079	0.7019	0.6695	0.6645	0.6358	—	0.6358	—	—
mm	Hole	—	0.7102	0.6753	0.6703	0.6467	0.6404	—	0.7102	0.6404
14–1.25	Plug	0.5505	0.5455	0.5185	0.5142	0.4904	—	0.4904	—	—
mm	Hole	—	0.5525	0.5235	0.5192	0.4997	0.4944	—	0.5525	0.4944
10–1.0	Plug	0.3931	0.3886	0.3675	0.3637	0.3450	—	0.3450	—	—
mm	Hole	—	0.3948	0.3719	0.3681	0.3525	0.3482	—	0.3948	0.3482
3/8–24	Plug	0.3739	0.3667	0.3468	0.3430	0.3228	—	0.3228	—	—
in.	Hole	—	0.3750	0.3512	0.3479	0.3364	0.3299	—	0.3750	0.3299
1/4–32	Plug	0.2490	0.2431	0.2287	0.2255	0.2107	—	0.2107	—	—
in.	Hole	—	0.2500	0.2328	0.2297	0.2208	0.2162	—	0.2500	0.2162

Preignition Rating of Spark Plugs for Ground Vehicles

SAE Recommended Practice

Report of Electrical Equipment Technical Committee approved December 1947.

Equipment—SC-17.6 engine[1] with cylinder barrel having knurled and Lubrited surface treatment and piston rings chromium plated in top two grooves.

Speed—The nominal speed is to be 2700 rpm but is not to be over 2765 when firing nor under 2670 when motoring.

Compression Ratio—5.6 to 1.

Spark Advance—30 deg before TDC.

Ignition Source—Ignition source is Bendix CR4-1 magneto.

Spark-Plug Installation—Short-reach plugs in short-reach hole and long-reach plugs in long-reach hole.

Fuel—98% 1 benzol, 2% SAE 60 aviation oil, with 3.0 cc tetraethyl lead.[2]

Fuel Injection Pressure—300 ± 50 psi.

Fuel Injection Timing—The fuel injection-pump port shall begin to close 60 ± 5 deg of crankshaft angle after TDC on intake stroke

Fuel Circulation Rate—½ ± ¼ gal per min.

Fuel Injection Pump—The gallery pressure of the fuel injection pump is to be 15 ± 2 psi.

Mixture Strength—The mixture strength is that which gives maximum thermal plug temperature.

Inlet-Air Temperature—225 ± 5 F.

Inlet-Air Humidity—75 ± 25 grains of moisture per pound of dry air.

Coolant—The coolant shall be distilled water plus 1 g of 20 Mule Team Borax per gal as an inhibitor. City water may be used if total dissolved solids are not excessive.

Coolant Quantity—Coolant level is maintained at middle of sight glass on coolant heat exchanger.

Coolant Pressure—The pressure in coolant tower is to be 23 to 28 psi. Cylinder-head pressure is approximately 20 psi higher.

Coolant Flow—5 ± ½ gal per min.

Jacket Inlet Temperature—265 ± 5 F.

Crankcase Oil—Oil is to be SAE 60 aviation oil (AN-O-8, Grade 1120).

Oil Pressure—In main bearings, 95 ± 5 psi; in valve gear, 25 ± 5 psi.

Oil Temperature—190 ± 10 F.

Oil Quantity—Oil level is maintained at bottom edge of filler sight-glass opening.

Operating Conditions—The mixture strength is maintained at that giving the maximum thermal plug temperature, and the boost pressure is increased until failure occurs in the form of preignition. Boost pressure is then decreased in increments of 1 in. of Hg until the plug will operate continuously without preignition, the IMEP value for this boost pressure being considered the plug rating. Afterfiring in no instance is to be considered failure.

Engine condition is checked after the rating of every ten plugs by the use of a cold plug such as the LS 81. Engine condition is considered satisfactory if preignition is not obtained up to 100 IMEP above the value of the anticipated rating.

[1] An engine of this type may be obtained from the Laboratory Equipment Corporation, Mooresville, Indiana.

[2] This may be obtained from Standard Oil Co., Indiana as Formula No. L-6048.

Cigar-Lighter Switch Base

SAE Standard

Report of Electrical Equipment Technical Committee approved June 1949.

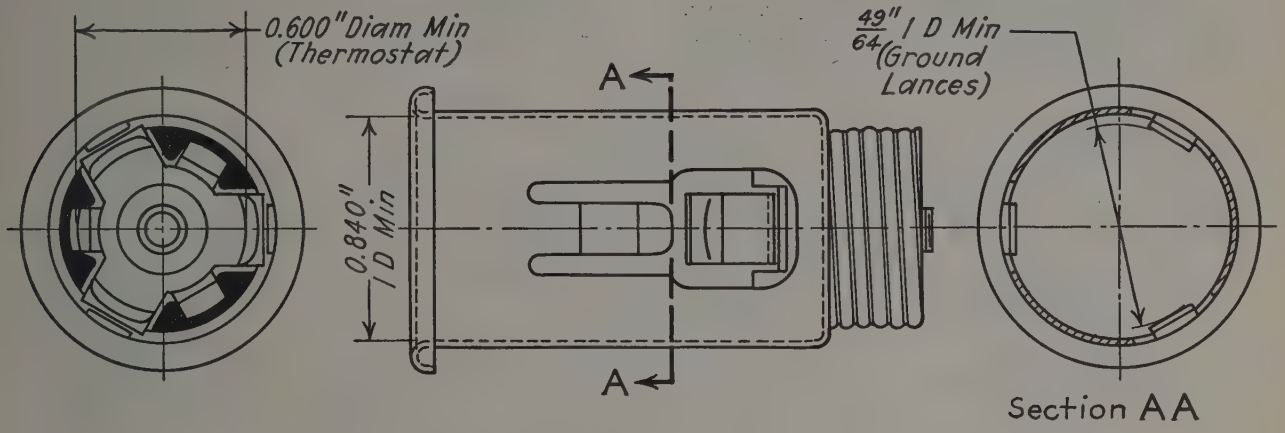


FIG. 1—CIGAR-LIGHTER SWITCH BASE

[*This Standard relates to the standard cigar-lighter switch base, but manufacturers of plugs for use with accessories such as trouble lamps, bottle warmers, and razors are urged to observe the dimensions and other provisions given in this Standard.*]

Fig. 1 shows the cigar-lighter switch base and its dimensions. Live contact should be made with the center stud; however, if live contact is made with the plug entering bi-metal fingers, the plug should not exceed 0.700 in. in diameter and should have tapered lead and round corners to conform to the heating-element cup (Fig. 2) as made by cigar-lighter manufacturers.

The body of the plug back of the contact end should be large enough to serve as a centering guide when inserting it into the socket, to prevent distortion of the bi-metal fingers. The diameter of the body plug should be 0.828 to 0.834 in.

(The ground fingers should be so designed as not to interfere with or catch on the ground lances in the switch base when the plug is rotated.)

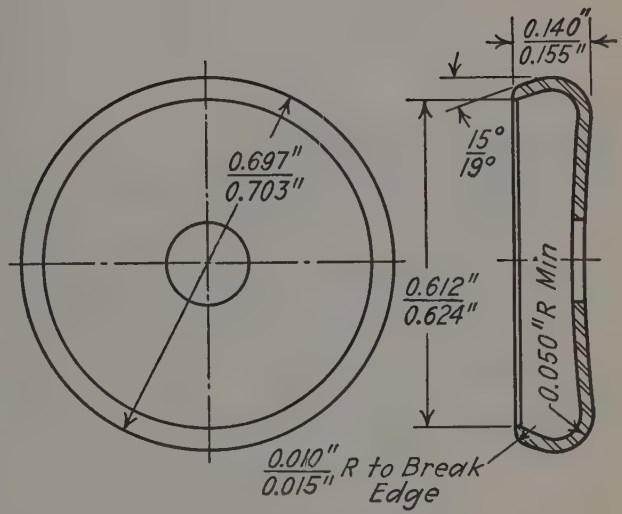


FIG. 2—HEATING-ELEMENT CUP

Lighting-Switch Mountings

SAE Recommended Practice

Report of Electrical Equipment Division approved January 1945.

[*The accompanying switch mountings are recommended for use by the body and vehicle manufacturers and as a guide to switch manufacturers to promote simplification in production and interchangeability in use. Further detail standardization of these switches was not considered feasible because of the various designs of switch mechanisms furnished by the switch manufacturers.*]

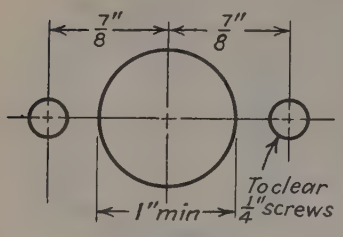


FIG. 1—BEAM CONTROL
(Formerly termed foot-dimmer switch)

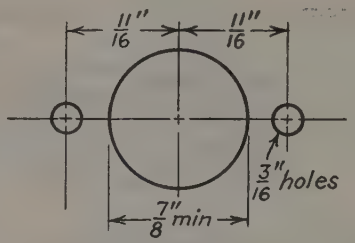


FIG. 2—DOOR JAMB

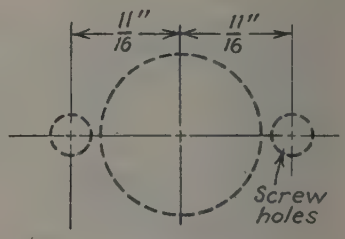


FIG. 3—PILLAR

Headlight Switching

SAE Recommended Practice

Report of Lighting Division approved January 1934.

The switching of automobile headlights from the country or upper beam to the beam used for passing other cars (the meeting beam in the asymmetric type and the lower beam in the dual-beam type) should be by means of a foot-operated switch located in a position convenient to the driver's left foot.

The switch should have no dead point and means[1] should be provided for indicating to the driver that the country or upper beam is on.

[1] A colored jewel light of very low candlepower mounted in the instrument panel is considered effective.

Headlamp Mountings

SAE Recommended Practice

Report of Lighting Division approved June 1936.

[*In order to facilitate setting and maintaining the proper adjustment of headlight beams on motor vehicles in use, the following requirements for headlamp design and mounting have been adopted in the belief that they will be followed in general practice and be equally applicable to new designs of headlamps and headlamp mountings.*]

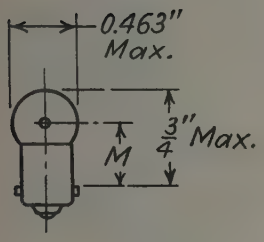
Headlamps and headlamp mountings shall be so designed and constructed that:

1. The axes of the light beams may be adjusted to the left, right, up, or down from the designed setting, the amount of adjustability to be determined by practical operating conditions and the type of equipment.
2. The adjustments may be conveniently made by one man with the tools ordinarily available.
3. When the headlamps are secured, the aim will not be disturbed under ordinary conditions of service.

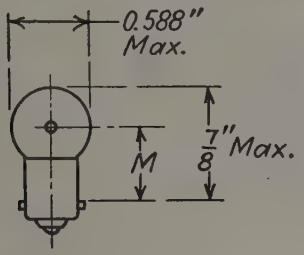
Lamp Bulbs and Bases

SAE Standard

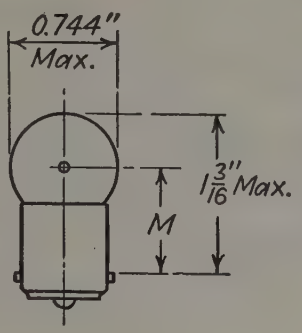
Report of Lighting Division approved March 1918 and last revised by Lighting Technical Committee January 1949.



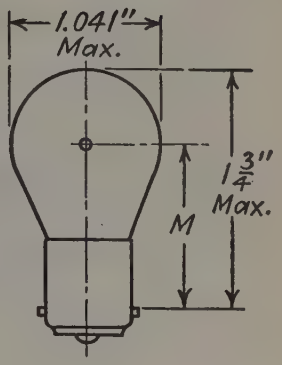
Bulb G-3½
Base A-1



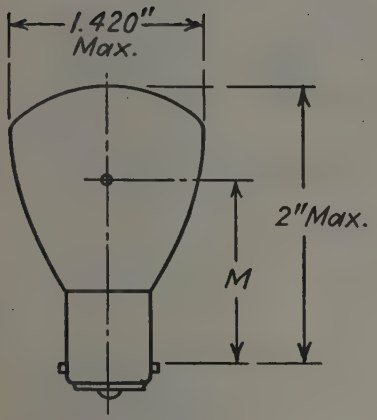
Bulb G-4½
Base A-1



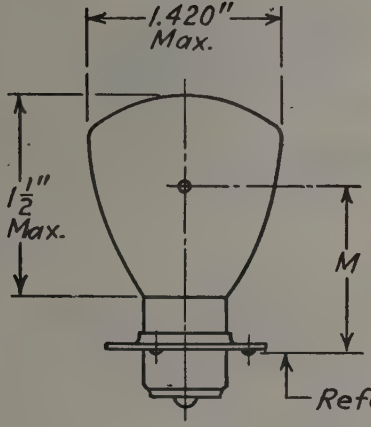
Bulb G-6
Base B-1, B-2, C-2



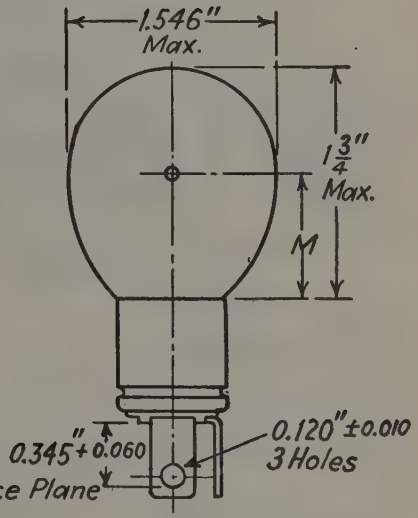
Bulb S-8
Base B-1, B-2, C-2,
D-1, D-2, G-1



Bulb RP-11
Base B-1, B-2, G-1

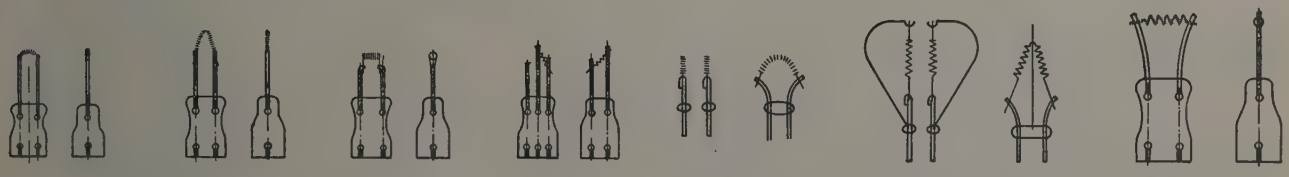


Bulb RP-11
Base F-1, F-2



Bulb B-12
Base H-3

FIG. 1—BULB TYPES

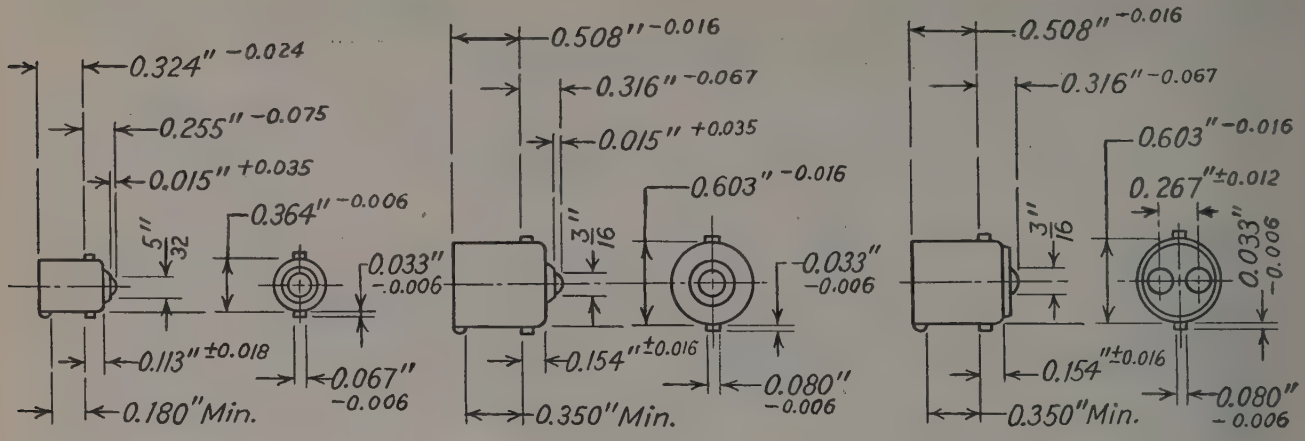


C-2R C-2V C-6 C-12 2C2R in Series 2C2V in Series CC-6

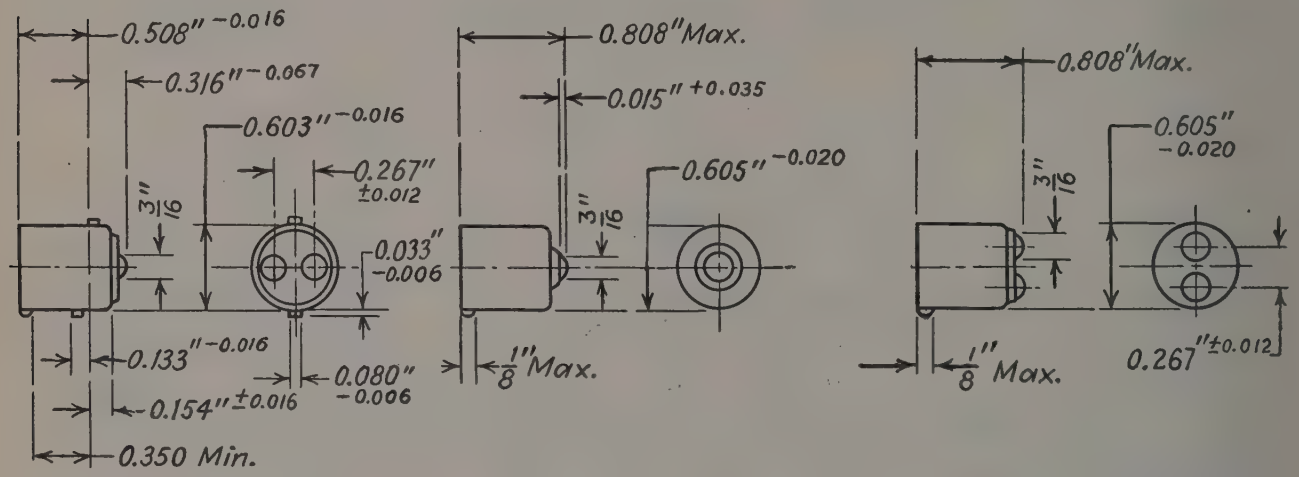
FIG. 2—FILAMENT TYPES

Note—Filament center length is measured from the center of the filament

(*Continued on next page.*)

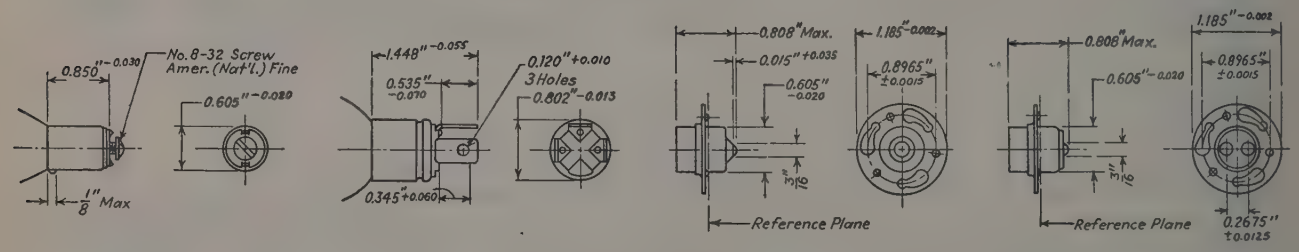


Type A-1, Min Bay, S.C. Type B 1, Cand Bay, S.C. Type B-2, Cand Bay, D.C.



Type C-2, Index. Cand Bay, D.C. Type D-1, Pinless Cand, S.C. Type D-2, Pinless Cand, D.C.

FIG. 3—BASE TYPES



Type G-1, Screw Terminal Type H-3, Three Contact Lugs Type F-1, Cand Prefocus, S.C. Type F-2, Cand Prefocus, D.C.

FIG. 4—BASE TYPES

Gaging—The maximum base diameters are to be measured by ring gages and minimum base diameters by snap gages in accordance with Table 1 and are to apply to all parts of the base except within 1/8 in. from the bulb end.

Sealed-Beam Headlamp Units—In order to make all Sealed-Beam units interchangeable, the dimensions of both the all-glass and composite types shall conform to Fig. 5. For photometric-

TABLE 1—*Ring-Gage, Snap-Gage, and Base Diameters*

LAMP-BASE TYPE	BASE DIAMETER, MAX +0.000	RING-GAGE DIAMETER	SNAP GAGE
B-1, B-2, C-2	0.603, −0.016	0.603	0.587
D-1, D-2, G-1, F-1, F-2	0.605, −0.020	0.605	0.585
H-3	0.802, −0.013	0.802	0.789

test requirements, see the SAE Recommended Practice for Sealed-Beam Headlamp Units for Motor Vehicles.

Mounting and Retaining Rings—The mounting and retaining rings for Sealed-Beam headlamp units are shown in Fig. 6.

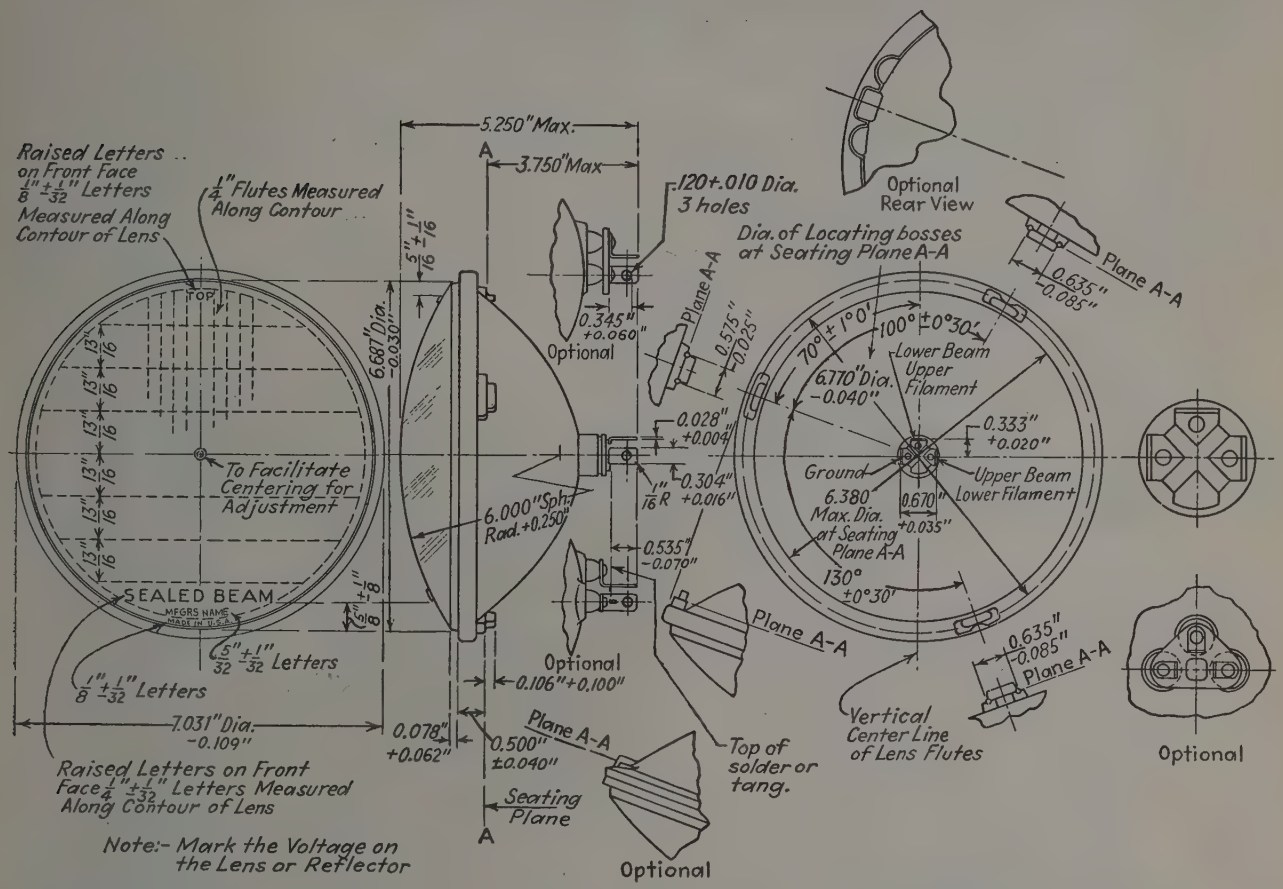


FIG. 5—SEALED-BEAM HEADLAMP UNIT

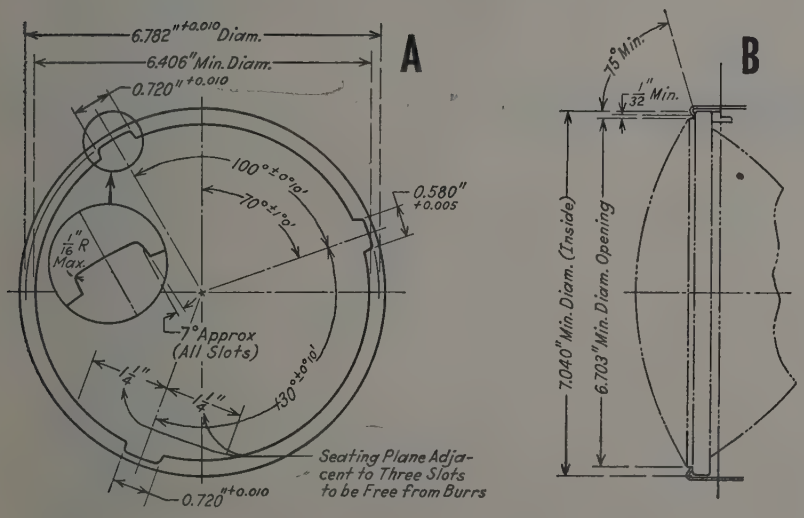


FIG. 6—(A) FRONT VIEW OF SLOTS OR NOTCHES FOR SEALED-BEAM-HEADLAMP MOUNTING RING OR LAMP BODY, AND (B) SEALED-BEAM-UNIT RETAINING RING

Lamp Bulbs and Sealed-Beam Units

SAE Recommended Practice

Report of Lighting Division approved March 1918 and last revised by Lighting Technical Committee January 1951.

TABLE 1—*Motor-Vehicle Electric Lamp Bulbs*[a] *(for New Designs or Original Equipment)*

TYPE OF SERVICE[b]	TRADE NO.	DESIGN		RATED AVERAGE LAB LIFE AT DESIGN VOLTS	MAX AMPS AT DESIGN VOLTS	FILAMENT				BULB		MAX OVER-ALL LENGTH, IN.	BASE			
		Cp	Volts			Type	Center length, in.	Focal center length tol, + or −	Axial-align. tol, + or −	Type	Max diam, in.		Type	Design	Con-tacts	Plane of pins or major-locking eyelet with respect to filament, deg
6–8 Volt Circuits																
1, 2	51	1	7.5	1000	0.25	C-2R	½	3/32	3/32	G-3½	0.463	15/16	A-1	Min Bay.	SC	—
1, P	55	2	7.0	500	0.45	C-2R	½	3/32	3/32	G-4½	0.588	1 1/16	A-1	Min Bay.	SC	—
L,M,P,T	63	3	7.0	1000	0.73	C-2R	¾	3/32	3/32	G-6	0.744	1 7/16	B-1	Cand Bay.	SC	—
3	81	6	6.5	500	1.14	C-2R	¾	3/32	3/32	G-6	0.744	1 7/16	B-1	Cand Bay.	SC	—
3, D	1129	21	6.4	200	2.91	C-2V	1¼	0.04	0.03	S-8	1.041	2	B-1	Cand Bay.	SC	90
4	1209S	32	6.1	125	4.30	C-6 Short	⅞	0.010	0.010	RP-11	1.420	2¼	F-1	Cand Pref	SC	90
7, F	1323	32	6.2	200	4.52	C-2V	⅞	0.010	0.010	RP-11	1.420	2¼	F-1	Cand Pref	SC	90
D,L,S,T	1154	21	6.4	200	2.97	C-6	1¼	0.04	0.03	S-8	1.041	2	C-2	Cand Bay.	DC	90
		3	7.0	1000	0.84	C-6	—	—	—	—	—	—	—	Indexing	—	—
6	2220	21	6.4	200	3.05	C-2V	1⅛	0.010	0.010	RP-11	1.420	2¼	F-2	Cand Pref	DC	90
		21	6.4	200	3.05	C-2V	—	—	—	—	—	—	—	—	—	—
5	2320	32	6.2	200	4.52	C-2V	1⅛	0.010	0.010	RP-11	1.420	2¼	F-2	Cand Pref	DC	90
		21	6.4	400	3.30	C-2V	—	—	—	—	—	—	—	—	—	—
12–16 Volt Circuits																
1, 2	57	1½ (nom)	14.0	1000	0.22	C-2V	½	3/32	3/32	G-4½	0.588	1 1/16	A-1	Min Bay.	SC	—
1, M,T	67	3	13.0	1000	0.41	C-2R	13/16	3/32	3/32	G-6	0.744	1 7/16	B-1	Cand Bay.	SC	—
D,M	89	6	13.0	750	0.63	C-2R	¾	3/32	3/32	G-6	0.744	1 7/16	B-1	Cand Bay.	SC	—
D	1141	21	12.8	500	1.50	C-2R	1¼	0.04	0.03	S-8	1.041	2	B-1	Cand Bay.	SC	90
3	1142	21	12.8	500	1.50	C-2R	1¼	0.04	0.03	S-8	1.041	2	B-2	Cand Bay.	DC	90
4, 7, F	1327	32	12.75	300	2.33	C-2V	⅞	0.010	0.010	RP-11	1.420	2¼	F-1	Cand Pref	SC	90
D,P,S,T	1016	21	12.8	300	1.47	C-2R	1¼	0.04	0.03	S-8	1.041	2	C-2	Cand Bay.	DC	0
		6	13.0	1000	0.63	C-12	—	—	—	—	—	—	—	Indexing	—	—
3	F42T6/W	—	—	—	—	Fluo-rescent	—	—	—	T-6	—	40	—	—	—	—

[a] Complete lists of available bulbs, including specials and replacements, are issued by the bulb manufacturers.
[b] Letter and number designations are defined as follows: 1—Instrument; 2—Indicator; 3—Interior; 4—Spot; 5—Motorcycle Headlamp; 6—City Delivery-Truck Headlamp; 7—Farm Tractor; D—Turn Signal; F—Fog; L—License; M—Marker; P—Parking; S—Stop; T—Tail.

(Continued on next page.)

TABLE 2—*Sealed Units and Bulbs Used in Units (for New Designs or Original Equipment)*

TYPE OF SERVICE[a]	TRADE NO.	DESIGN		RATED AVERAGE LAB. LIFE AT DESIGN VOLTS	MAX AMPS AT DESIGN VOLTS	FILAMENT TYPE	BULB		MAX OVERALL LENGTH, IN.	BASE		
		Watts	Volts				Type or trade no.	Max diam, in.		Type	Design	Contacts
6–8 Volt Circuits												
H	Unit	45W	6.4	300	7.38	C-6	2400	7.031	5¼	H-3	Lug Term.	3
		35W	6.4	500	5.74	C-6	—	—	—	—	—	—
H	4030	45W	6.4	300	7.38	C-6	PAR-56	7.031	5¼	H-3	Lug Term.	3
		35W	6.4	500	5.74	C-6	—	—	—	—	—	—
F	Unit	35W	6.2	300	5.93	C-6	2404	5.70	4⅛	G-1	Screw Term.	SC
F	4012A	35W	6.2	300	5.93	C-6	PAR-46	5.70	4⅛	G-2	Screw Term.	DC
4	4535	30W	6.4	100	5.08	C-6 Short	PAR-46	5.70	4⅛	G-2	Screw Term.	DC
7	Unit	—	—	—	—	—	—	5.70	4⅛	G-2	Screw Term.	DC
7	4013	25W	6.4	300	4.1	C-6	PAR-46	5.70	4⅛	G-2	Screw Term.	DC
F	4015A	35W	6.2	300	5.93	C-6	PAR-36	4.46	2⅝	G-2	Screw Term.	DC
12–16 Volt Circuits												
H	Unit	50W	12.8	300	4.19	C-6	2412	7.031	5¼	H-3	Lug Term.	3
		40W	12.8	500	3.35	C-6	—	—	—	—	—	—
H	4430	50W	12.8	300	4.19	C-6	PAR-56	7.031	5¼	H-3	Lug Term.	3
		40W	12.8	500	3.35	C-6	—	—	—	—	—	—
F	Unit	35W	12.8	300	2.93	C-6	2414	5.70	4⅛	G-1	Screw Term.	SC
F	—	35W	12.8	—	—	C-6	PAR-46	5.70	4⅛	G-2	Screw Term.	DC

[a] Letter and number designations are defined as follows: 4—Spot; F—Fog; 7—Tractor; H—Sealed-Beam Headlamp.

Lighting Equipment for Motor Vehicles

SAE Standard

Report of Lighting Division approved May 1942 and last revised by Lighting Technical Committee January 1951.

[*This Standard covers general requirements for various types of lighting equipment. Particular requirements for specific types of equipment are given in separate SAE Standards and SAE Recommended Practices.*

SAE lighting specifications are subject to frequent change to keep pace with technical advances. This SAE Standard is intended for use by State or Federal authorities having regulatory powers over motor vehicles, but its inclusion in State or Federal laws where flexibility of revision is lacking is discouraged.]

A—Scope—This Standard covers the requirements and methods for laboratory test—including vibration, moisture, dust, corrosion, color, and photometric tests for

Electric Headlamps
Sealed-Beam Headlamp Units
Electric Supplementary Driving Lamps
Electric Supplementary Passing Lamps
Fog Lamps
Motorcycle and Motor-Driven Cycle Lamps
Tail Lamps
Stop Lamps
License-Plate Lamps
Turn-Signal Units
Turn-Signal Operating Units
Clearance, Side-Marker, Identification, and Parking Lamps
Back-Up Lamps
Reflex Reflectors
School-Bus Warning-Signal Lamps
Electric Emergency Lanterns
Liquid-Burning Emergency Flares

B—Samples for Test—Sample lamps submitted for laboratory test should be representative of the devices as regularly manufactured and marketed. Where necessary each sample should include all accessory equipment peculiar to the device and necessary to operate it in normal manner. Each sample should also be mounted in its normal operating position on a supporting bracket designed to be bolted rigidly to the vibration rack. Dust and photometric tests may be made on a second set of unmounted samples, if desired, to expedite completion of tests.

C—Lamp Bulbs—Unless otherwise specified, lamp bulbs used

in the tests should be supplied by the laboratory and should be representative of standard bulbs in regular production. They should be selected for accuracy in accordance with specifications approved by the National Bureau of Standards and should be operated at their rated mean spherical candlepower during the tests. Where special bulbs are specified, they should be submitted with the devices and the same or similar bulbs used in the tests and operated at their rated mean spherical candlepower.

D—Laboratory Facilities—The laboratory should be equipped with all facilities necessary to make accurate physical and optical tests in accordance with established laboratory practices.

E—Vibration Test—A sample unit, as mounted on the support supplied, shall be bolted to the anvil end of the table of the vibration-test machine and vibrated approximately 750 cpm through a distance of ¼ in. The table shall be spring mounted at one end and fitted with steel calks on the under side of the other end. These calks are to make contact with the steel anvil once during each cycle at the completion of the fall. The rack shall be operated under a spring tension of 60 to 70 lb. This test shall be continued for 1 hr.

The unit shall then be examined. Any unit showing evidence of material physical weakness, lens or reflector rotation, displacement, or rupture of parts shall be considered to have failed. (See SAE General Information on Vibration-Test Machine.)

F—Moisture Test—A sample unit shall be mounted in its normal operating position with all drain holes open and subjected to a precipitation of 0.1 in. of water per min, delivered at an angle of 45 deg from a nozzle with a solid cone spray. During the moisture test the lamp shall revolve about its vertical axis at a rate of 4 rpm. This test shall be continued for 12 hr. The water shall then be turned off and the unit permitted to drain for 1 hr.

The unit shall then be examined. Moisture accumulation in excess of 2 cc shall constitute a failure.

G—Dust Test—A sample unit with any drain hole closed shall be mounted in its normal operating position, at least 6 in. from the wall in a box measuring 3 ft in all directions, containing 10 lb of fine powdered cement in accordance with ASTM Specification for Portland Cement, C 150-42. At intervals of 15 min, this dust shall be agitated by compressed air or fan blower by projecting blasts of air for a 2-sec period in a downward direction into the dust in such a way that the dust is completely and uniformly diffused throughout the entire cube. The dust is then allowed to settle. This test shall be continued for 5 hr.

After the dust test the exterior surface shall be cleaned; and if the maximum candlepower is within 10% of the maximum as compared with the condition after the unit is cleaned inside and out, it shall be considered adequately dust tight. Where sealed units are used, the dust test shall not be required.

H—Corrosion Test—A sample unit shall be subjected to a salt-spray (fog) test in accordance with the latest ASTM B 117—44T for a period of 50 hr, consisting of two periods of 24-hr exposure and one-hr drying time each.

There shall be no evidence of excessive corrosion immediately after the above test has been completed, which would affect the proper functioning of the device.

I—Color Test—Refer to SAE Standard on Color Specification for Electric Lamps.

J—Photometric-Test Points—In locating the test points, the following nomenclature shall apply: The line formed by the intersection of a vertical plane through the lamp axis, or if a pair of lamps is tested, the line formed by the intersection of a median vertical plane parallel to the lamp axes with the test screen is designated as V. The line formed by the intersection of a horizontal plane through the lamp center or centers and the test screen is designated as H. The point at the intersection of these two lines is designated as H-V. The other points on the screen are designated by similar symbols to indicate the number of degrees of arc above or below H and the number of degrees of arc to the left or right of V; for example: 4D-3L is a point 4 deg below H and 3 deg to the left of V, and 1U-V is a point 1 deg above H in the median vertical plane.

K—Out-of-Focus Tests on Unsealed Units—Tests shall be made for each of four out-of-focus filament positions, except that the complete distribution may be omitted. Where conventional bulbs with two-pin bayonet bases are used, candlepower tests shall be made with the light source 0.060 in. above, below, ahead, and behind the designed position. If prefocused bulbs are used, the limiting positions at which tests are made shall be 0.020 in. above, below, ahead, and behind the designed position. The minimum values for out-of-design position shall be 80% of the in-design position. The lamp may be reaimed for each of the out-of-focus positions of the light source.

L—Candlepower Requirements—The photometric minimum candlepower requirements for tail lamps, clearance, side-marker, identification, and parking lamps, stop lamps, turn-signal lamps, and school-bus warning lamps are given in Table 1.

(*Continued on next page.*)

TABLE 1—*Photometric Minimum Candlepower Requirements*[a]

TEST POINTS		TAIL LAMPS[b]	CLEARANCE, SIDE-MARKER, IDENTIFICATION, AND PARKING LAMPS			STOP LAMPS		TURN SIGNALS						SCHOOL-BUS WARNING LAMPS	
								Class B Type I			Class A Type I				
		Red	Red	Amber[c]	White	Red	Amber	Red	Amber[c]	White	Red	Amber[c]	White	Red	Amber
10°U	—5°L	0.25	0.25	0.75	1.5	2	6	2	6	12	10	30	60	10	30
	—V	0.25	0.25	0.75	1.5	2	6	2	6	12	10	30	60	10	30
	—5°R	0.25	0.25	0.75	1.5	2	6	2	6	12	10	30	60	10	30
5°U	—20°L	—	—	—	—	—	—	—	6	12	10	30	60	10	30
	—10°L	0.25	0.25	0.75	1.5	2	6	2	6	12	25	75	150	25	75
	—5°L	0.25	0.25	0.75	1.5	5	15	5	15	30	25	75	150	25	75
	—V	0.25	0.25	0.75	1.5	10	30	10	30	60	25	75	150	25	75
	—5°R	0.25	0.25	0.75	1.5	5	15	5	15	30	25	75	150	25	75
	—10°R	0.25	0.25	0.75	1.5	2	6	2	6	12	25	75	150	25	75
	—20°R	—	—	—	—	—	—	—	6	12	10	30	60	10	30
H	—20°L	0.25	0.25	0.75	1.5	2	6	2	6	12	10	30	60	10	30
	—10°L	0.25	0.25	0.75	1.5	5	15	5	15	30	25	75	150	25	75
	—5°L	0.25	0.25	0.75	1.5	10	30	10	30	60	25	75	150	25	75
	—V	0.25	0.25	0.75	1.5	15	45	15	50	100	100	300	600	100	300
	—5°R	0.25	0.25	0.75	1.5	10	30	10	30	60	25	75	150	25	75
	—10°R	0.25	0.25	0.75	1.5	5	15	5	15	30	25	75	150	25	75
	—20°R	0.25	0.25	0.75	1.5	2	6	2	6	12	10	30	60	10	30
5°D	—20°L	—	—	—	—	—	—	—	—	—	10	30	60	10	30
	—10°L	0.25	0.25	0.75	1.5	2	6	2	6	12	25	75	150	25	75
	—V	0.25	0.25	0.75	1.5	10	30	10	30	60	25	75	150	25	75
	—10°R	0.25	0.25	0.75	1.5	2	6	2	6	12	25	75	150	25	75
	—20°R	—	—	—	—	—	—	—	—	—	10	30	60	10	30
10°D	—5°L	—	—	—	—	—	—	—	—	—	10	30	60	10	30
	—V	0.25	0.25	0.75	1.5	2	6	2	6	12	10	30	60	10	30
	—5°R	—	—	—	—	—	—	—	—	—	10	30	60	10	30

[a] A tolerance of −20% in above candlepower values shall be allowed for 12-v filaments.
[b] A tail lamp shall not project more than 10 candlepower above horizontal. When the tail lamp is optically combined with other lamps, the candlepower of the other lamp or lamps shall not be less than 3 times the candlepower of the tail lamp at any test point on or above horizontal.
[c] Where the color is between white and amber, the lamp shall be tested in accordance with candlepower requirements for white light.

Vibration-Test Machine

SAE General Information

Report of Lighting Division approved January 1940.

[This SAE General Information contains an illustration giving the essential arrangement and dimensions for a test machine which is satisfactory for the vibration test required by the SAE laboratory test specifications for motor-vehicle electric lamps and is published as a guide for building these machines.]

TABLE 1—*Cam-Profile Radii*[a]

POINT	RAD, IN.	POINT	RAD, IN.	POINT	RAD, IN.	POINT	RAD, IN.	POINT	RAD, IN.
1	0.5625	5	0.5840	9	0.6320	13	0.6800	17	0.7280
2	0.5625	6	0.5960	10	0.6440	14	0.6920	18	0.7400
3	0.5650	7	0.6080	11	0.6560	15	0.7040	19	0.7470
4	0.5720	8	0.6200	12	0.6680	16	0.7160	20	0.7500

[a] The cam width is to be between ½ and 1 in.

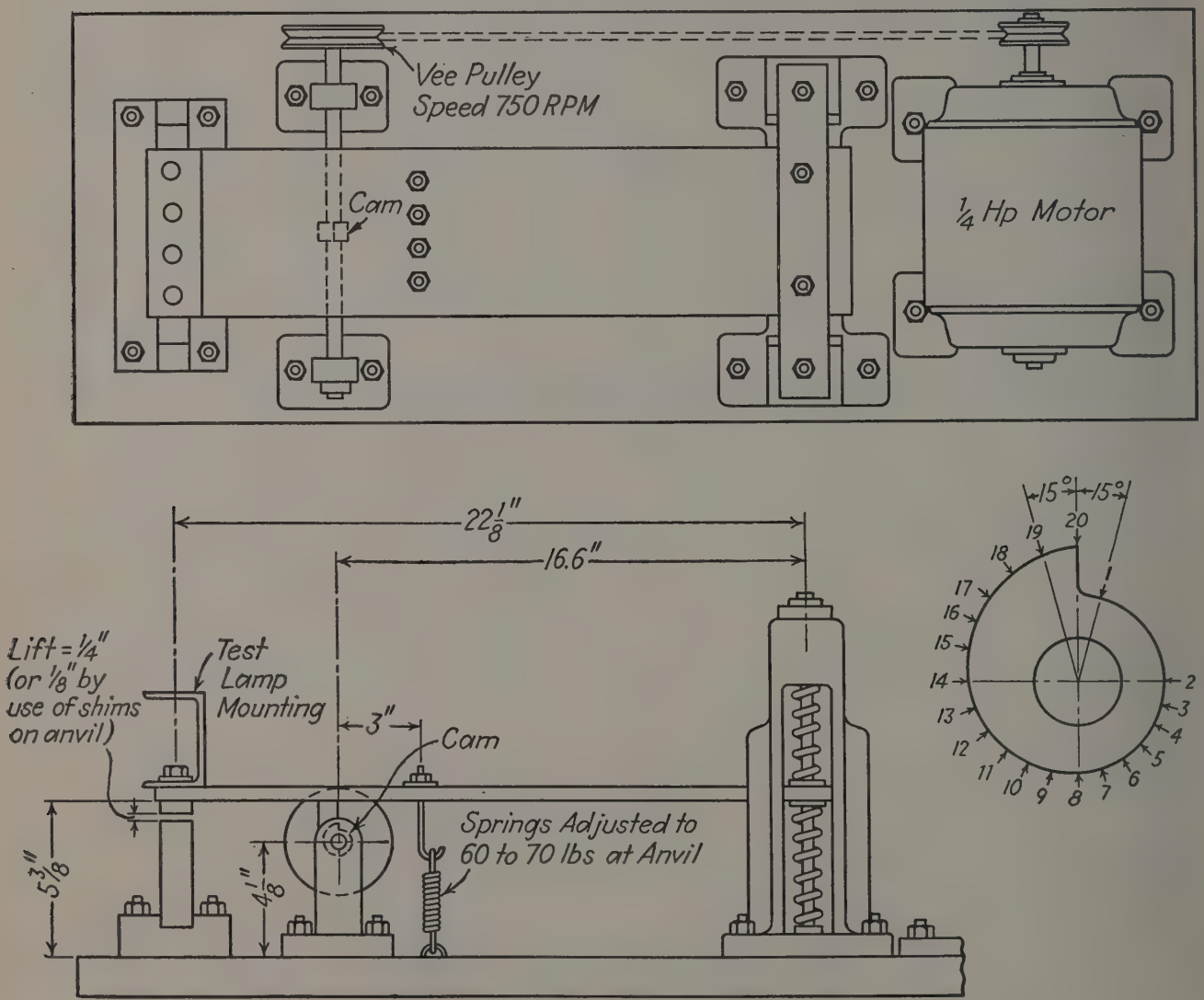


FIG. 1—VIBRATION-TEST MACHINE

Color Specification for Electric Lamps

SAE Standard

Report of Lighting Division approved January 1942.

[*SAE lighting specifications are subject to frequent change to keep pace with technical advances. This SAE Standard is intended for use by State or Federal authorities having regulatory powers over motor vehicles, but its inclusion in State or Federal laws where flexibility of revision is lacking is discouraged.*]

Scope of Specification—The purpose of this specification is to provide standards for colors employed in motor-vehicle lighting equipment. It is intended to cover the colors of red, amber (yellow), and uncolored (white) transmitting media.

Red—Transmitting media which are to be classed as red must conform to the requirements for color specified below and may be examined for compliance with the requirements by comparison with a red limit glass. This glass has been prepared so that it represents the closest permissible approach to amber (yellow) and has at the same time the maximum purity of color. A red transmitting medium shall not be acceptable if it is paler or yellower than the light-limit standard glass when the two are illuminated by incandescent lamp light.

In case of doubt or samples close to the limit, resort must be had to spectrophotometric determinations of the color of the sample.

Amber (Yellow)—Transmitting media which are to be classed as amber (yellow) must conform to the requirements for color specified below and may be examined for compliance with the requirements by comparison with amber (yellow) limit glasses. These glasses have been prepared so that one represents the closest permissible approach to red and the other the closest permissible approach to yellow-green, both having at the same time the maximum purity of color. An amber (yellow) transmitting medium shall not be acceptable if it is paler or greener than the light-limit standard or redder than the dark-limit standard when the lens and the standards are illuminated by incandescent lamp light.

In case of doubt or samples close to the limit, resort must be had to spectrophotometric determinations of the color of the sample.

Uncolored—Transmitting media which are to be classed as uncolored must not materially change the color of the source illuminating the lens.

Trichromatic Coefficient Specification—The fundamental specification of the above colors expressed in terms of the standard observer, coordinate system, and Illuminant A (incandescent lamp operated at 2848 K, Planck's constant, C_2, taken equal to 14,350 micron degrees) adopted by the International Commission on Illumination in 1931 and described in the Journal of the Optical Society of America, Volume 23, October, 1933, page 359, is as follows for the above colors:

Red—For the purposes of these specifications, a red transmitting medium is a medium which, when illuminated with ICI Standard Illuminant A, transmits light for which y is not greater than 0.335 and z is not greater than 0.002.

Amber (Yellow)—For the purposes of these specifications, an amber (yellow) transmitting medium is a medium which, when illuminated by ICI Standard Illuminant A, transmits light for which y is not less than 0.398, y is not greater than 0.429, and z is not greater than 0.007.

Uncolored—For the purposes of these specifications, an uncolored transmitting medium is a medium which, when illuminated by ICI Standard Illuminant A, transmits light for which the values of x and y do not differ by more than 0.01 from the values x and y for the source illuminating the specimen.

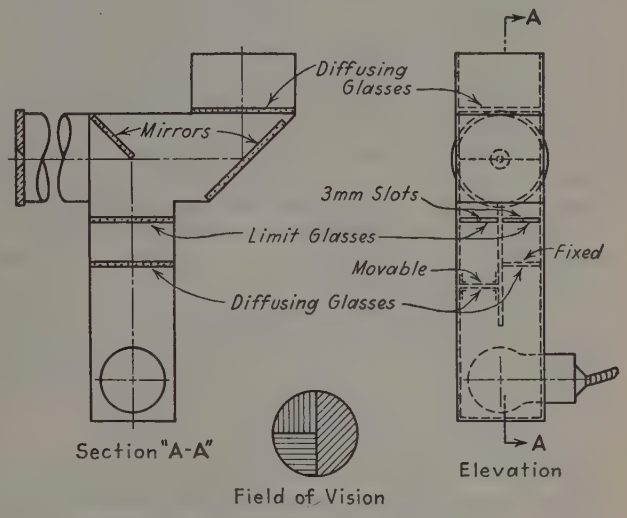


FIG. 1—COLOR COMPARISON APPARATUS

Visual Comparison of Colors—A device which may be used for visually comparing the color of transmitting media used in automotive lighting equipment and the limit glass or glasses is shown in Fig. 1. It consists of a lamp holder capable of mounting and operating any standard bulb which is specified for such equipment. The bulb is so positioned that the light from it passes through the standard-limit glass or glasses as well as diffusing glasses before being reflected from a mirror to the observer. The position of one of the diffusing glasses is adjustable so that by altering its position, the brightness of these two portions of the field of view may be made the same. A similar diffusing plate and mirror are so positioned that the observer also views the automotive lighting equipment being examined. The device is adjusted so that a brightness match is obtained between the test source and the limit-glass beams. The color is then examined to determine conformance with the limits.

Electric Headlamps for Motor Vehicles

SAE Standard

Report of Lighting Division approved March 1918 and last revised by Lighting Technical Committee December 1948.

[*The study of automotive headlighting requirements dates back to 1914 when electric lighting was first applied to motor vehicles. The first joint Illuminating Engineering Society-Society of Automotive Engineers headlighting specifications were adopted in 1918 to provide a single, all-purpose beam as a compromise between road illumination and glare. As operating speeds increased more cars appeared on the road; and as cars were provided with softer springs and lower driver's seats, these and other factors tended to make lighting with the single-beam lamps less satisfactory. Attention gradually shifted to the need for two beams, one aimed high enough to reveal obstacles and turns at a safe distance ahead and the other aimed low enough to avoid glare, the driver to be responsible for using the proper beam at the right time as specified in the dual-beam specifications adopted in 1930. Specifications for multiple-beam headlamps of the asymmetric type were adopted in 1933. In 1936 the specifications were revised to cover all types of multiple-beam headlamps and to comply with the 1936 SAE Headlighting Inspection Code for Motor Vehicles. In January 1937 the entire specification including the location and values for photometric-test points, was revised to designate minimum laboratory optical-test requirements for approval purposes.*

SAE lighting specifications are subject to frequent change to keep pace with technical advances. This SAE Standard is intended for use by State or Federal authorities having regulatory powers over motor vehicles, but its inclusion in State or Federal laws where flexibility of revision is lacking is discouraged.]

Definitions—*Headlamp*—A headlamp is a major lighting device used to provide general illumination ahead of the vehicle.

Multiple-Beam Headlamps—Headlamps which are arranged to permit the driver of the vehicle to use any one of two or more distributions of light on the road

Country or Upper Beams—One or more beams intended primarily for distant illumination and for use on the open highway when not meeting other vehicles.

Traffic or Lower Beams—One or more beams low enough on the left to avoid glare in the eyes of oncoming drivers and intended for use in congested areas and on highways when meeting other vehicles within a distance of 500 ft.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric-Test Points—See Section J of SAE Standard on Lighting Equipment for Motor Vehicles.

Out-of-Focus Tests for Unsealed Units—See Section K of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric Tests—The light sources in the headlamps shall be located in the designed position as specified by the manufacturer. A photometer shall be set up at not less than 60 ft from the headlamps.

Aiming adjustments shall be made on one country or upper beam only.

The headlamps shall be aimed on a country or upper beam so the vertical center of the zone of highest intensity falls at the horizontal line through the photometer axis.

The country or upper beam of each headlamp shall be aimed laterally with respect to the single vertical line through the photometer axis in the same manner as the manufacturer specifies said beam shall be aimed on the car with respect to a vertical line ahead of each lamp. Correction should be made for the difference between the distance from lamp to photometer and the distance from lamp to aiming screen specified in the manufacturers' instructions.

Where conventional bulbs with two-pin bayonet bases are used, candlepower tests shall be made with the light source at the designed positions and also in positions 0.060 in. above, below, ahead, and behind the designed position. If prefocused bulbs are used, the limiting positions at which tests are made shall be 0.020 in. above, below, ahead, and behind the designed position.

Each pair of headlamps shall be aimed only once for each posi-

POSITION	CP MIN
½U—1R and 1L	15,000
½U—3R and 3L	7,000
½U—6R and 6L	3,000
H—1R and 1L	25,000
H—3R and 3L	10,000
H—6R and 6L	4,000
½D—1R and 1L	15,000
½D—3R and 3L	7,000
½D—6R and 6L	3,000
1D—6R to 6L	3,000
1D—9R to 9L	2,000
2D—12R to 12L	1,000

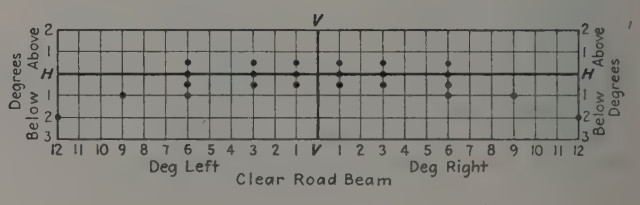


FIG. 1—MINIMUM TEST POINT VALUES FOR CAR HALF LOADED

POSITION	CP MAX	CP MIN
1½U—4L	1000	—
1½U—1L	2000	—
½U—4L	2000	—
½U—1L	4000	—
½D—4L	4000	—
½D—1L	7000	—
2D—V	—	7000
2D—9L	—	2000
3D—12L	—	1000

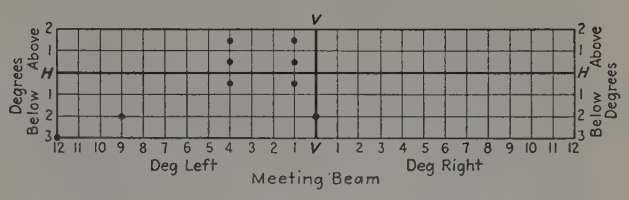


FIG. 2—TEST POINT VALUES FOR CAR HALF LOADED

tion of the light source.

Maximum Beam Intensity—The maximum intensity of the beam at any point shall be 75,000 cp.

Country or Upper Beam—Fig. 1 shows the test point values for a car which is half loaded.

Traffic or Lower Beam—Fig. 2 shows the test point values for a car which is half loaded.

Sealed-Beam Headlamp Units for Motor Vehicles

SAE Recommended Practice

Report of Lighting Division approved January 1949 and last revised by Lighting Technical Committee November 1947.

[*Need for improvement in motor vehicle lighting from the economic, safety, and regulatory points of view lead the Automotive Manufacturers Association to set up an industry committee on headlighting to formulate a single, uniform optical specification available for use by the entire industry. Eventually the Sealed-Beam type of headlighting unit was developed by the committee and accepted by the industry and state administrative authorities.*

SAE lighting specifications are subject to frequent change to keep pace with technical advances. This SAE Recommended Practice is intended for use by State or Federal authorities having regulatory powers over motor vehicles, but its inclusion in State or Federal laws where flexibility of revision is lacking is discouraged.]

Application—These specifications apply only to the Sealed-Beam type of headlighting units. The SAE Standard on Electric Headlamps for Motor Vehicles applies to other types of headlamps which may be in current use.

Scope—These specifications cover the requirements for physical interchangeability and photometric test of Sealed-Beam headlamp units.

For dimensional specifications on Sealed-Beam headlamp units see SAE Standard on Lamp Bulbs and Bases.

Definitions—*Sealed-Beam Unit*—An integral and indivisible optical assembly with the name "Sealed Beam" branded on the lens.

Country or Upper Beam—A clear road beam intended primarily for distant illumination and for use on the open highway when not meeting other vehicles.

Traffic or Lower Beam—A beam low enough on the left to avoid glare in the eyes of oncoming drivers and intended for use in congested areas and on highways when meeting other vehicles within a distance of 500 ft.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric-Test Points—See Section J of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric Test—Photometric tests shall be made with the photometer at a distance of 60 ft from the lamps. Units shall be operated at their rated voltage during the tests.

The country or upper beam shall have a sufficiently well-defined high-intensity area or hot spot to permit the aiming of both beams from the center of this area.

The upper beam from each lamp shall be aimed visually so that the zones of maximum intensity superimpose at the photometric-test plate, and so that the geometric center of the zone

POSITION	CP MAX	CP MIN
3U—to right and left	3,000	—
3U—3R and 3L	—	1,000
2U—to right and left	5,000	—
2U—3R and 3L	—	2,000
1U—to right and left	8,000	—
1U—3R and 3L	—	4,000
H—V	—	25,000
½D—V	—	40,000
½D—3R and 3L	—	20,000
½D—6R and 6L	—	6,500
½D—9R and 9L	—	3,000
½D—12R and 12L	—	1,500
1D—V	—	35,000
2D—V	—	10,000
3D—V	—	5,000
3D—9R and 9L	—	3,000
3D—12R and 12L	—	1,500
4D—V	10,000	—

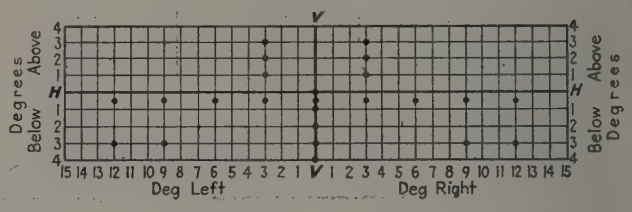


FIG. 1—TEST POINT VALUES FOR CAR UNLOADED

POSITION	CP MAX	CP MIN
1½U—IR to right	1,500	—
1U—1L to left	800	—
½U—1R to right	3,000	—
½U—1L to left	1,000	
½D—1R to right	6,000	—
½D—1L to left	2,000	
1½D—1R	—	10,000
1½D—2R	—	15,000
1½D—1L to left	6,000	—
2D—12R and 12L	—	1,500
2D—15R and 15L	—	1,000
4D—4R	25,000	—

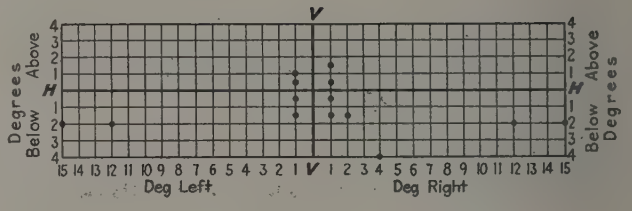


FIG. 2—TEST POINT VALUES FOR CAR UNLOADED

of highest intensity falls 0.6 deg vertically below the photometer axis.

The combined beams from the two lamps shall meet the specifications given below.

Maximum Beam Intensity—The maximum intensity of the beam shall not exceed 75,000 cp.

Country or Upper Beam—Fig. 1 shows the test point values for a car which is unloaded. To provide for manufacturing variations, a tolerance of ±¼ deg in location may be allowed for any test point.

Traffic or Lower Beam—Fig. 2 shows the test point values for a car which is unloaded. To provide for manufacturing variations, a tolerance of ±20% in cp and of ±¼ deg in location may be allowed for any test point.

Sealed-Beam Headlamp Testing Specifications

SAE General Information

Approved for publication by Lighting Technical Committee January 1951.

[*This specification was developed by the Engineering Liaison Committee of the Automobile Manufacturers Association and has been used to check production quality since Sealed-Beam headlamps were introduced in 1940.*]

Vibration Test—A complete headlamp, with a Sealed-Beam unit mounted in position, as mounted on the support supplied, shall be bolted to the anvil end of the table of the vibration rack and vibrated approximately 750 times per min through a distance of ¼ in. The table shall be spring mounted at one end and fitted with steel calks on the underside of the other end. These calks are to make contact with the steel anvil end during each cycle at the completion of the fall. The rack should be operated under a spring tension of 60 to 70 lb. This test shall be continued for 1 hr.

The headlamp and unit shall then be examined. Any headlamp or unit showing evidence of material physical weakness, displacement, or rupture of parts affecting aim more than 2.00 in. at 25 ft shall be considered to have failed.

Corrosion Test—A completely assembled headlamp with a Sealed-Beam unit shall be subjected to a 20% salt spray solution for a period of 50 hr, consisting of two periods of 24 hr exposure, and 1 hr of drying after each period at a temperature of 95 F (35 C). A drain hole shall be provided at any point where water is likely to collect.

There shall be no evidence of general rusting of the ferrous parts immediately after the above test has been completed, particularly about the adjustment screws and between other moving parts.

Aiming-Adjustment Tests—The headlamp-unit mounting must be provided with independent vertical and horizontal aiming adjustment. The adjustment screws must be so positioned that neither the vertical nor horizontal aim will deviate more than 4.00 in. from the horizontal or vertical planes respectively, at a distance of 25 ft, through an angle of +4 deg to −4 deg.

The self-locking devices used to hold aiming screws in position must continue to operate satisfactorily up to 10 adjustments on each screw over a length of screw thread of plus and minus ⅛ in.

The mechanism, including the aiming adjustment, must be so designed as to prevent the unit from receding into the lamp body when an inward pressure of 50 lb is exerted on the outer surface of the lens.

A minimum aiming adjustment of plus and minus 4 deg must be provided in both the vertical and horizontal planes.

Gasket Requirements—Gaskets, when used to seal between movable parts, must be so designed or attached that they will not hinder or interfere with the ease of reassembly in service when replacing a burned-out unit.

Unit Holding-Ring Requirements—Positive means must be provided for holding the Sealed-Beam unit to the headlamp-unit mounting ring. The fastening means shall be deemed adequate if it will withstand and hold the Sealed-Beam unit securely in its proper position at the end of 25 replacements.

A clearance of at least 1/32 in. must be provided between the retaining-ring lugs and the mounting-ring lugs when a unit having a flange thickness of 0.500 in. is assembled in the mounting ring and the retaining ring is assembled loosely over it.

Proper Seating of Sealed-Beam Unit—The Sealed-Beam-unit seating areas on the headlamp-unit mounting ring must be kept free from sharp burrs and other protuberances that might cause unit breakage or improper seating. This area will include a distance of 1¼ in. each side of the center of the locating-lug notch.

Connector Requirements—The voltage drop between any Sealed-Beam contact and the connector at the end of a 3 in. wire lead from the socket shall not exceed 40 mv with a 10 amp load.

Headlighting Inspection Code

SAE Recommended Practice

Report of Lighting Division approved January 1937 and last revised January 1942. This SAE Recommended Practice conforms with the American Standard Code for Inspection Requirements for Motor Vehicles, ASA D7-1939.

[*This code is intended only for the inspection and maintenance of headlighting equipment on motor vehicles that are in operation.*

The original SAE code, adopted in 1937, was drafted for use in preparing Interstate Commerce Commission regulations for trucks and buses in interstate operation under the 1935 Motor-Carrier Act. Subsequently the SAE code served as a basis for Section 2, Lighting Systems, of the American Standard Code for Inspection Requirements for Motor Vehicles, ASA D7-1939. The ASA inspection requirements for lighting systems were adopted by the Society as the SAE Recommended Practice in January 1940.

SAE lighting specifications are subject to frequent change to keep pace with technical advances. This SAE Recommended Practice is intended for use by State or Federal authorities having regulatory powers over motor vehicles, but its inclusion in State or Federal laws where flexibility of revision is lacking is discouraged.]

1. **Definitions of Beams**

(*a*) *Single Beam*—A single beam provides only one fixed beam that is not adjustable from the driver's seat.

(*b*) *Multiple Beam*—A multiple beam provides two or more beams which may be selected by the driver.

(*c*) *Symmetrical Beam*—A symmetrical beam has both sides symmetrical with respect to the median vertical plane.

(*d*) *Asymmetrical Beam*—An asymmetrical beam is one in

which both sides are not symmetrical with respect to the median vertical plane.

Vehicles in use today are equipped with two distinct types of headlamp equipment—multiple- or selective-beam lamps and single- or fixed-beam lamps.

Single- or fixed-beam lighting is generally recognized as unsatisfactory because the beams must be aimed low enough to avoid glare to oncoming drivers, therefore, cannot give satisfactory illumination on the road.

Multiple-beam lighting includes a "traffic" or "meeting" or "passing" beam and an "open road" or "driving" beam.

The inspector should see that the driver understands how to use the multiple-beam headlamps so as to obtain the best road lighting with minimum glare to other users of the highway.

2. General Headlamp-Testing Requirements

(*a*) *Preparation for Aiming*—Before checking beam aim, the inspector shall see that no tire is noticeably deflated and shall rock the vehicle sideways. Beam aim shall be checked with no load in the vehicle other than the driver in the front seat. Faulty wheel alignment or improper tracking of the rear axle should be taken into consideration before the headlamp inspection is made. Experience indicates that it is advisable to maintain the light output of the lamp well up toward the normal new-lamp value as indicated in Section 4. The reference to higher standards mentioned in Sections 4 and 6 should in each case be drawn to the attention of the car owner.

(*b*) *Screen*—Beams should be inspected for focus and aim, either on a screen at a distance of 25 ft ahead of the headlamps or with inspection equipment which gives essentially equivalent or more accurate results. If a screen is used, it should be of adequate size with a matte-white surface well shaded from extraneous light and used on a flat-level paved surface. Provisions should be made for moving the screen so that it can be aligned parallel with the rear axle, and a horizontal line drawn perpendicular from the center line of the screen will pass an equal distance between the two headlamps.

The screen should be provided with a fixed vertical center line, four laterally adjustable vertical tapes, and two vertically adjustable horizontal tapes, as shown on Fig. 1. The two movable horizontal tapes should be located on the screen at the upper and lower limits called for in the specifications with reference to the plane on which the vehicle rests, not the floor on which the screen rests. The four movable vertical tapes should be located on the screen at the left and right limits called for in the specification

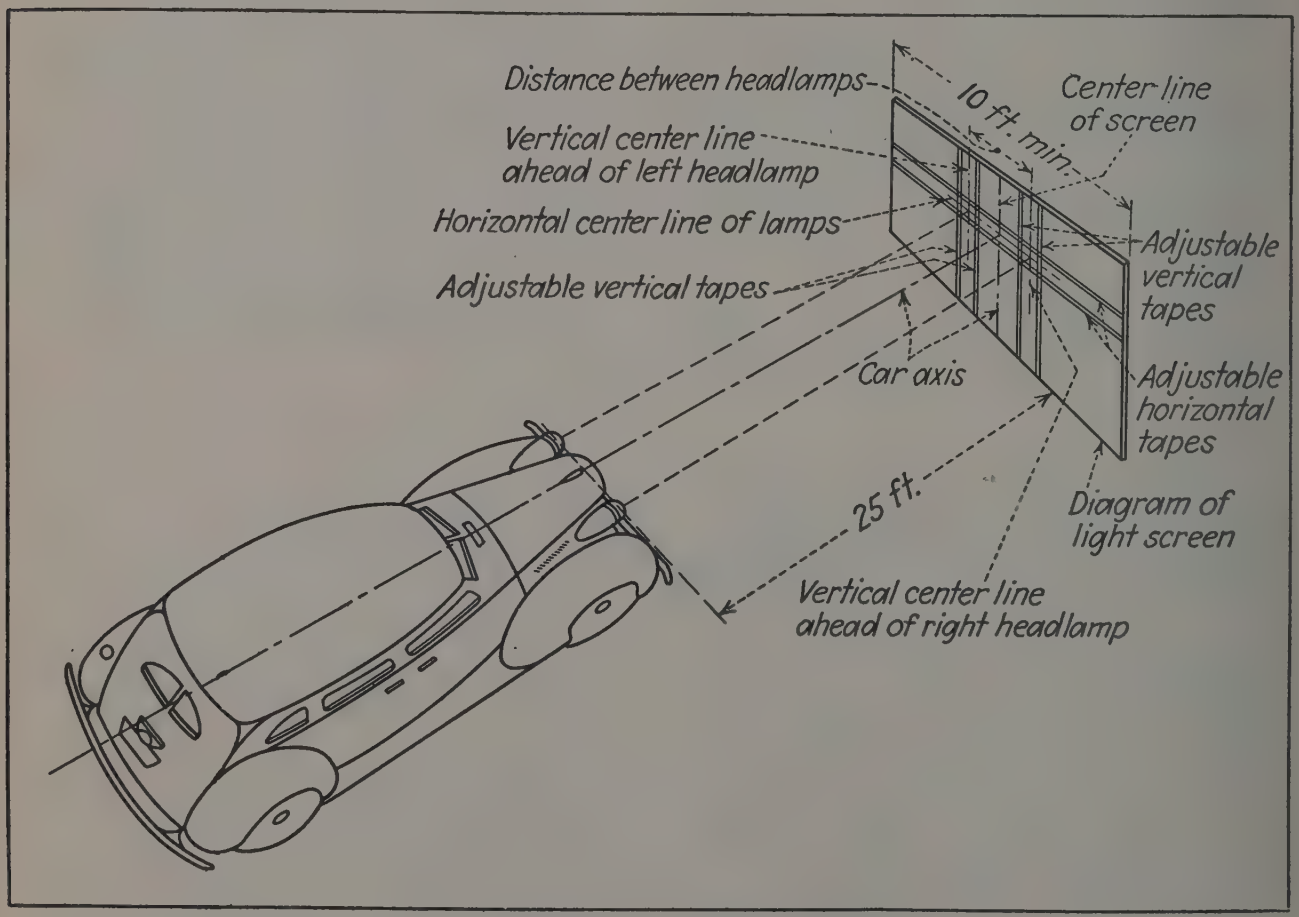


FIG. 1—CAR POSITION WITH RESPECT TO SCREEN

with reference to center lines spaced to either side of the fixed center line on the screen by the amount the lamps are to the left and right.

3. **General Lamp-Inspection Limits**—General lamp inspection includes the following types of lamp: head, rear, clearance, signal, marker, and adverse-weather.

Any of the following defects shall be cause for rejection:

(*a*) Any bulb in any lamp required by law or regulation or in any adverse-weather lamp which fails to burn.

(*b*) An improperly connected circuit which does not light the proper filaments for the different switch positions.

(*c*) A cracked, broken, or missing lens.

(*d*) A lens that is rotated, upside down, wrongside out, or is otherwise incorrectly installed.

(*e*) A lens marked 'left' or 'right,' not appropriately installed.

(*f*) A multiple-beam headlamp lens, the name of which does not correspond with the name stamped on the lamp body.

(*g*) A lamp which is not securely fastened to the vehicle.

(*h*) A lamp showing a beam of color contrary to law or regulation.

(*i*) Any defects in wiring or lighting equipment that would be likely to influence adversely the effectiveness of the lighting performance.

(*j*) Any auxiliary equipment placed on, in, or in front of the headlamp which is not a part of the original standard equipment.

(*k*) Beam-indicator lights which do not indicate the proper beam to the driver and which do not operate satisfactorily.

4. **Lamp-Output Inspection**—Approval shall be refused when the light produced by any headlamp or auxiliary lamp designed for use in place of a headlamp (whether measured in terms of maximum beam candlepower, average beam candlepower, lamp output, or other term) is less than 50% of the normal new-lamp value.

(A light output of 70% or more of new-lamp value, while not required in this code, is desirable. See Section 2a for use.)

5. **Lamp-Focus Inspection**—Focus inspection shall be made visually on a screen.

Approval shall be refused when the beam from any headlamp or any auxiliary lamp is noticeably out of focus.

6. **Lamp-Aim Inspection**—All of the following values are based on a 25 ft test distance. (Refer to Figs. 2, 3, 4, and 5.)

(*a*) *Horizontal Beam Aim* (*Sideways*)

(1) *Symmetrical Beam*—Upper beam. (All single-beam lamps, all double-beam symmetrical lamps, all adverse-weather lamps.) Approval shall be refused if the center of the high intensity zone is more than 6 in. to the right or left of straight ahead.

(A tolerance of not more than 4 in., while not required in this code, is desirable. See Section 2a for use.)

(2) *Asymmetrical Beam*—Upper beam. (Multibeam, Supersafe, Tribeam left lamp, Flexbeam and Solar right lamp.) Approval shall be refused if the left edge of the stray light which is to the left of the high intensity zone extends

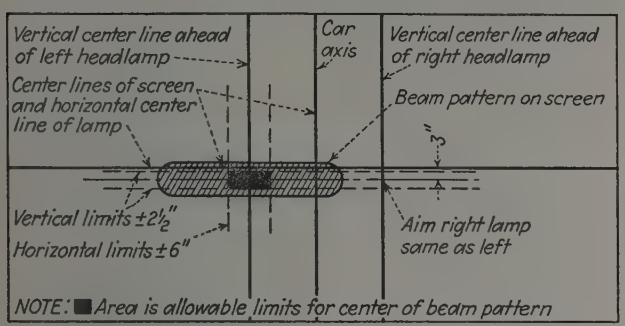

Vertical center line ahead of left headlamp
Car axis
Vertical center line ahead of right headlamp
Center lines of screen and horizontal center line of lamp
Beam pattern on screen
2"
Vertical limits ±2½"
Horizontal limits ±6"
Aim right lamp same as left
NOTE: ■ Area is allowable limits for center of beam pattern

FIG. 2 —AIM INSPECTION FOR ALL SYMMETRICAL TWO-BEAM LAMPS

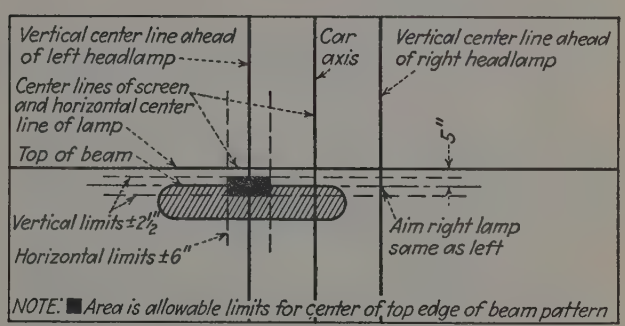

Vertical center line ahead of left headlamp
Car axis
Vertical center line ahead of right headlamp
Center lines of screen and horizontal center line of lamp
Top of beam
5"
Vertical limits ±2½"
Horizontal limits ±6"
Aim right lamp same as left
NOTE: ■ Area is allowable limits for center of top edge of beam pattern

FIG. 3 —AIM INSPECTION FOR ALL SINGLE-BEAM LAMPS

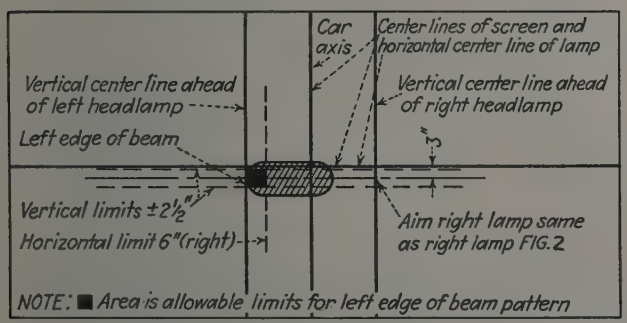

Car axis
Center lines of screen and horizontal center line of lamp
Vertical center line ahead of left headlamp
Vertical center line ahead of right headlamp
Left edge of beam
3"
Vertical limits ±2½"
Horizontal limit 6"(right)
Aim right lamp same as right lamp FIG. 2
NOTE: ■ Area is allowable limits for left edge of beam pattern

FIG. 4 —AIM INSPECTION FOR ASYMMETRICAL-BEAM LAMPS (MULTIBEAM, SUPERSAFE, TRIBEAM)

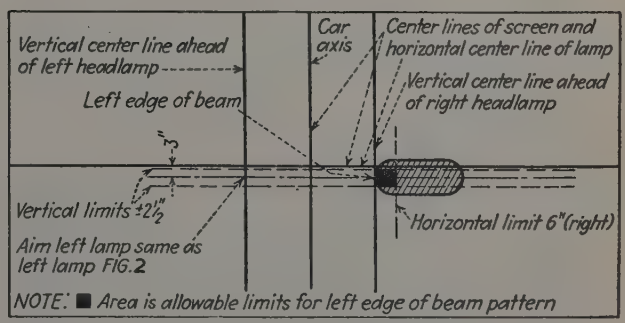

Vertical center line ahead of left headlamp
Car axis
Center lines of screen and horizontal center line of lamp
Vertical center line ahead of right headlamp
Left edge of beam
3"
Vertical limits ±2½"
Aim left lamp same as left lamp FIG. 2
Horizontal limit 6"(right)
NOTE: ■ Area is allowable limits for left edge of beam pattern

FIG. 5 —AIM INSPECTION FOR ASYMMETRICAL-BEAM LAMPS (FLEXBEAM, SOLAR)

to the left of straight ahead or is more than 6 in. to the right of straight ahead.

(A tolerance of not more than 4 in., while not required in this code, is desirable. See Section 2a for use.)

(3) *Asymmetrical Beam*—Upper beam. (Multibeam, Tribeam right lamp, Flexbeam left lamp.) Approval shall be refused if the center of the high intensity zone is more than 6 in. to the right or left of straight ahead.

(A tolerance of not more than 4 in., while not required in this code, is desirable. See Section 2a for use.)

(*b*) *Vertical Beam Aim (Up and Down)*

All beams from buses, coupes, roadsters, and long wheelbase cars should preferably be aimed near the upper limit. All beams from trucks and short wheelbase five passenger cars should preferably be aimed near the lower limit, with no load in vehicle other than driver in front seat. In case of loaded trucks, due allowance should be made for loading.

(1) *Multiple-Beam Headlamps*—Upper Beam. Approval shall be refused if the center of the high intensity zone is aimed higher or lower than 3 in. below the lamp center level. The tolerance applicable for this inspection shall be plus or minus 2½ in.

(A tolerance of not more than plus or minus 1 in., while not required in this code, is desirable. See Section 2a for use.)

(2) *Single-Beam Headlamps*—Approval shall be refused if the top of the beam from any single-beam headlamp is aimed higher or lower than 5 in. below the lamp center level. The tolerance shall be plus or minus 2½ in.

(A tolerance of not more than plus or minus 1 in., while not required in this code, is desirable. See Section 2a for use.)

(3) *Adverse-Weather Lamps*—Approval shall be refused if the top of the beam to the left of the prolongation of the extreme left side of the vehicle is aimed higher or lower than 4 in. below the lamp center level. The tolerance shall be plus or minus 2½ in.

Electric Supplementary Driving Lamps

SAE Recommended Practice

Report of Lighting Division approved January 1941 and last revised by Lighting Technical Committee December 1948.

[*Electric supplementary driving lamps are for use with headlamps other than Sealed-Beam headlamps. The supplementary lamp should be turned off when approaching or closely following other cars. Switching should be arranged so that when the supplementary driving lamp switch is closed, the lamp will light only when the upper or country beam from the regular headlamps is in use.*

SAE lighting specifications are subject to frequent change to keep pace with technical advances. This SAE Recommended Practice is intended for use by State or Federal authorities having regulatory powers over motor vehicles, but its inclusion in State or Federal laws where flexibility of revision is lacking is discouraged.]

Definition—A supplementary driving lamp is a unit used to supplement the country or upper beam from headlamps other than Sealed Beam. It is not intended for use alone or with the traffic or lower beam.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric-Test Points—See Section J of SAE Standard on Lighting Equipment for Motor Vehicles.

Out-of-Focus Tests on Unsealed Units—See Section K of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric Test—Photometric tests shall be made with the photometer at a distance of at least 60 ft from the lamp.

At-Focus Tests—The light source shall be located in the designed position as specified by the manufacturer.

The beam from the lamp shall be aimed vertically with reference to the horizontal line through the photometer axis as specified by the manufacturer.

The beam from the lamp shall be aimed laterally with reference to the vertical center line through the photometer axis in the same manner as the manufacturer specifies that it be aimed on the car with respect to the vertical center line ahead of the lamp.

Candlepower values shall be recorded at 1 deg intervals for all points within the angles bounded by 3U, 4D, 12L, and 12R, except that in the cases of beams which are symmetrical laterally, the complete distribution may be recorded for the left half only.

The beam from the lamp should meet the photometric specifications listed below when it is aimed to center the maximum

intensity on the photometer axis, except that when the maximum exceeds 25,000 cp, the 25,000 cp point directly above the maximum intensity should be aimed at the photometer axis.

POSITION	CP MAX	POSITION	CP MIN
3U—3L to 3R	3,000	H—3L to 3R	7,500
2U—3L to 3R	5,000	1D—6L to 6R	2,500
1U—3L to 3R	8,000	2D—6L to 6R	1,500
H—V	25,000	H—V	15,000

The maximum anywhere not lower than 1D should be 50,000 cp.

An aiming tolerance of ± ¼ deg should be allowed for manufacturing variations. An additional tolerance of ± 20% shall be allowed for 12-v filaments.

Out-of-Focus Tests on Unsealed Units—Similar tests shall be made for each of four out-of-focus filament positions, except that the complete distribution may be omitted. Where conventional bulbs with two-pin bayonet bases are used, candlepower tests shall be made with the light source 0.060 in. above, below, ahead, and behind the designed position. If prefocused bulbs are used, the limiting positions at which tests are made shall be 0.020 in. above, below, ahead, and behind the designed position.

The beam from each lamp may be reaimed in accordance with the instructions above for each of the out-of-focus positions of the light source.

Electric Supplementary Passing Lamps

SAE Recommended Practice

Report of Lighting Division approved January 1941 and last revised by Lighting Technical Committee December 1948.

[*SAE lighting specifications are subject to frequent change to keep pace with technical advances. This SAE Recommended Practice is intended for use by State or Federal authorities having regulatory powers over motor vehicles, but its inclusion in State or Federal laws where flexibility of revision is lacking is discouraged.*

Aiming and Usage

For greatest visibility, with reasonable limitation of glare to approaching drivers, the left edge of the stray light immediately to the left of the high intensity zone should be aimed at the vertical line through the lamp center, at 25 ft. The top of the high intensity zone should be aimed at the level of the passing-lamp center at 25 ft, car unloaded. The unit should be turned off when traveling winding roads and in congested areas in cities. It should be wired so that it can be turned on or off only with the lower or traffic beam of the regular headlamps. In event means are provided to permit turning the passing lamp on or off conveniently—when the lower beam is on—without removing the hands from the steering wheel, an aim 3 in. higher than that recommended above is desirable.]

Definition—A passing lamp is a unit intended to supplement the lower or traffic beam from headlamps, including Sealed Beam.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric-Test Points—See Section J of SAE Standard on Lighting Equipment for Motor Vehicles.

Out-of-Focus Tests on Unsealed Units—See Section K of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric Test—Photometric tests shall be made with the photometer at a distance of at least 60 ft from the lamp.

At-Focus Tests—The light source shall be located in the designed position as specified by the manufacturer.

The beam from the lamp shall be aimed vertically with reference to the horizontal line through the photometer axis as specified by the manufacturer.

The beam from the lamp shall be aimed laterally with reference to the vertical center line through the photometer axis in the same manner as the manufacturer specifies that it be aimed on the car with respect to the vertical center line ahead of the lamp.

Candlepower values shall be recorded at 1 deg intervals for all points within the angles bounded by 2U, 1½D, 12L, and 12R, except that in the cases of beams which are symmetrical laterally, the complete distribution may be recorded for the left half only.

The beam from the lamp should meet the photometric specifications listed below when it is aimed in accordance with the manufacturer's service instructions.

POSITION	CP MAX
1U—1L to L and above	400
½U—1L to L	500
½D—1L to L	1000
1½D—1L to L	3000
2U—1R to R and above	1000
1U—1R to R	3000
H—1R to R	7000
1½D—2R to 4R	10,000 min

An aiming tolerance of ± ¼ deg should be allowed on individual points. An additional tolerance of ± 20% shall be allowed for 12-v filaments.

Out-of-Focus Tests on Unsealed Units—Similar tests shall be made for each of four out-of-focus filament positions, except that the complete distribution may be omitted. Where conven-

tional bulbs with two-pin bayonet bases are used, candlepower tests shall be made with the light source 0.060 in. above, below, ahead, and behind the designed position. If prefocused bulbs are used, the limiting positions at which tests are made shall be 0.020 in. above, below, ahead, and behind the designed position.

The beam from the lamp may be reaimed in accordance with the instructions above for each of the out-of-focus positions of the light source.

Fog Lamps

SAE Standard

Report of Lighting Division approved May 1937 and last revised by Lighting Technical Committee January 1951.

Definition—Fog, or adverse-weather lamps, are lamps which may be used in lieu of headlamps to provide road illumination under conditions of rain, snow, dust, or fog.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

The socket sleeve may be omitted from the reflector.

The sample should be accompanied by suitable instructions for adjustment, sufficient to enable the laboratory operator to locate the light source in its correct design position and to aim the beams. The laboratory report should include a copy of the instructions.

(Fog lamps are mounted lower than headlamps and are more subject to breakage.)

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—Where sealed units are used, the dust test shall not be required. For other types, see Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Color Test—The light from a fog lamp should be white to amber. See SAE Standard on Color Specification for Electric Lamps.

Photometric-Test Points—See Section J of SAE Standard on Lighting Equipment for Motor Vehicles.

Out-of-Focus Tests on Unsealed Units—See Section K of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric Test—Photometric tests shall be made with the photometer at a distance of at last 60 ft from the lamps.

At-Focus Tests—The light source shall be located in the design position as specified by the manufacturer.

Symmetrical beams shall be aimed straight ahead with the top of the beam 4 in. below the lamp center level at 25 ft. Asymmetrical beams shall be aimed with the left edge of the high-intensity zone straight ahead and the top of the beam 2 in. below the level of the lamp center at 25 ft.

Candlepower values shall be recorded at 1 deg intervals for all points within the angles bounded by 1U, 4D, 12L, and 12R, except that in the cases of beams which are symmetrical laterally, the complete distribution may be recorded for the left half only.

When aimed as above, the beam from a *single* fog lamp shall meet the following candlepower specifications:

POSITION	CP	POSITION	CP
Lines—8U to 90U	75 max	H—1R to R	1000 max
Line—4U	125 max	1½D—1L to 3L	8000 max
Line—2U	200 max	1½D—1R to 3R	2000 min
Line—1U	300 max	1½D—3R to 9R	1000 min
H—1L to L	500 max	3D—15L to 15R	1000 min

Maximum candlepower shall not be lower than 4 deg D. A tolerance of ±¼ deg shall be allowed for any test point. An additional tolerance of ±20% shall be allowed for 12-v filaments.

Out-of-Focus Tests—Similar tests shall be made for each of four out-of-focus filament positions, except that the complete distribution may be omitted. Where conventional bulbs with two-pin bayonet bases are used, candlepower tests shall be made with the light source 0.060 in. above, below, ahead, and behind the designed position. If prefocused bulbs are used, the limiting positions at which tests are made shall be 0.020 in. above, below, ahead, and behind the designed position.

The beam from the lamp may be reaimed in accordance with the instructions above for each of the out-of-focus positions of the light source.

Motorcycle and Motor-Driven-Cycle Headlamps

SAE Standard

Report of Lighting Technical Committee approved January 1949.

Definition—A motorcycle or motor-driven cycle headlamp is a major lighting device used to provide general illumination ahead of the vehicle. A motor-driven cycle is defined, by revisions approved in 1948 in Act V of the Uniform Code, as every motorcycle including every motor scooter with a motor which produces less than 5 hp and every bicycle with motor attached.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—Where sealed units are used, the dust test shall not be required. For other types, see Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Color Test—The light from the lamps should be uncolored. See SAE Standard on Color Specification for Electric Lamps.

Photometric-Test Points—See Section J of SAE Standard on Lighting Equipment for Motor Vehicles.

Out-of-Focus Tests on Unsealed Units—See Section K of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric Tests—Photometric tests shall be made at the design voltage of the bulb and with the photometer at a distance of at least 60 ft from the lamp.

At-Focus Tests—The light source or sources shall be located in the designed position as specified by the manufacturer.

The upper beam of a multiple-beam headlamp shall be aimed visually so that the geometric center of the zone of highest intensity falls 0.6 deg vertically below the lamp axis. The beam from a single-beam headlamp shall be aimed straight ahead with the top of the beam aimed vertically to obtain 2000 cp at H—V.

Candlepower values shall be recorded at 1 deg intervals for all points within the angle bounded by 1U, 4D, 12L, and 12R except that in the cases of beams which are symmetrical laterally, the complete distribution may be recorded for the left half only.

When aimed as above, the beams or beam from a single motorcycle or motor-driven cycle headlamp shall meet the following candlepower specifications:

Country or Upper Beam

POSITION	MOTORCYCLE	MOTOR-DRIVEN CYCLE	
	Multiple beam, cp	Multiple beam, cp	Single beam, cp
1U—4L	8000 max	8000 max	400 max
1U—V	8000 max	8000 max	200–1000
H—V	10000 min	2000 min	2000
½D—V	20000 min	5000 min	5000 min
½D—3L and 3R	4000 min	3000 min	3000 min
½D—6L and 6R	1000 min	750 min	750 min
1D—V	15000 min	5000 min	5000 min
2D—V	5000 min	3000 min	3000 min
3D—V	2500 min	1000 min	1000 min
3D—6L and 6R	750 min	500 min	500 min
4D—V	5000 max	5000 max	5000 max
Maximum anywhere	75000	—	—

Traffic or Lower Beam

POSITION	MOTORCYCLE	MOTOR-DRIVEN CYCLE
	Multiple beam, cp	Multiple beam, cp
1½U—1R to right	750 max	750 max
1U—1L to left	400 max	400 max
½U—1R to right	1500 max	1500 max
½U—1L to left	500 max	500 max
½D—1R to right	4000 max	4000 max
½D—1L to left	1500 max	1500 max
1½D—1L to left	5000 max	5000 max
2D—3R	3000 min	2000 min
2D—3L	2000 min	1500 min
2D—6L and 6R	750 min	500 min
4D—4R	12500 max	12500 max

An aiming tolerance of ±¼ deg on both upper and lower beams should be allowed for manufacturing variations. An additional tolerance of ±20% shall be allowed for 12-v filaments.

Tail Lamps

SAE Standard

Report of Lighting Division approved March 1918 and last revised by Lighting Technical Committee September 1950.

Definition—Tail lamps are lamps used to designate the rear of a vehicle by a warning light.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Color Test—The tail lamp indication shall be red. See SAE Standard on Color Specification for Electric Lamps.

Photometric Test—See Section L of SAE Standard on Lighting Equipment for Motor Vehicles. All beam candlepower measurements shall be made with a bar photometer, or equivalent, with the center of light at a distance of 4 ft from the photometer screen. In measuring distances and angles, the incandescent filament shall be taken as the center of light. The lamp axis shall be taken as the horizontal line through the light source and parallel to what would be the longitudinal axis of the vehicle if the lamp were mounted in its normal position on the vehicle.

Stop Lamps

SAE Standard

Report of Lighting Division approved February 1927 and last revised by Lighting Technical Committee September 1950.

Definition—Stop lamps are lamps giving a steady warning light to the rear of a vehicle, or train of vehicles, to indicate the intention of the operator of a vehicle to diminish speed or stop.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Color Test—The stop signal indication should be red or amber, preferably red. See SAE Standard on Color Specification for Electric Lamps.

Photometric Test—See Section L of SAE Standard on Lighting Equipment for Motor Vehicles. All beam candlepower measurements shall be made with a bar photometer, or equivalent, with the center of light at a distance of at least 4 ft from the photometer screen. In measuring distances and angles, the incandescent filament shall be taken as the center of light. The lamp axis shall be taken as the horizontal line through the light source and parallel to what would be the longitudinal axis of the vehicle if the lamp were mounted in its normal position on the vehicle.

License-Plate Lamps

SAE Standard

Report of Lighting Division approved March 1918 and last revised by Lighting Technical Committee January 1950.

Definition—A license-plate lamp is a lamp used to illuminate the license plate on the rear of a vehicle. If a tail lamp or a stop lamp is combined with a license-plate lamp, the combination should also meet the requirements in the specifications relating to these other devices.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Color—The license-plate lamp should be white.

Optical Requirements—(It is not intended that the unit should pass this test if only one of two lamps is operative.)

The lamp design should be such that, when mounted on a vehicle as intended, the angle between the plane of the license plate and the plane on which the vehicle stands will not exceed 90 deg plus or minus 30 deg.

The lamp and license-plate holder shall bear such relation to each other that at no point on the plate will the major portion of the light incident at that point make an angle of less than 8 deg to the plane of the plate.

The license-plate holder shall be designed and constructed so as to provide a substantially plane surface on which to mount the plate.

The license-plate window through which the light passes to the license plate shall be of such size and design as to permit the light to reach all parts of the license plate. The shadow cast by the edge of the license-plate window shall clear the far edge of the license plate, as represented by a line 6 in. from the bolt centers, by at least 1 in. measured perpendicularly to the plane of the plate.

All foot-candle measurements shall be made on a rectangular test plate of clean, white blotting paper mounted on the license-plate holder in the position ordinarily taken by the license plate. The face of the test plate shall be $\frac{1}{16}$ in. from the face of the license-plate holder.

For lamps used on all vehicles except motorcycles and motor-driven cycles, the test stations shall be located on the face of the test plate as in Fig. 1.

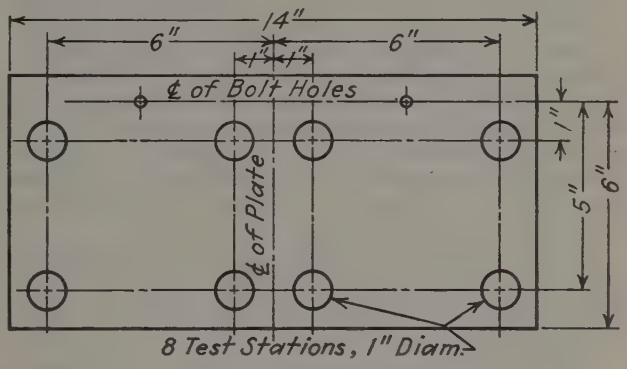


FIG. 1—VEHICLE LAMPS

For lamps used on motorcycles and motor-driven cycles, the test stations shall be located on the face of the test plate as in Fig. 2.

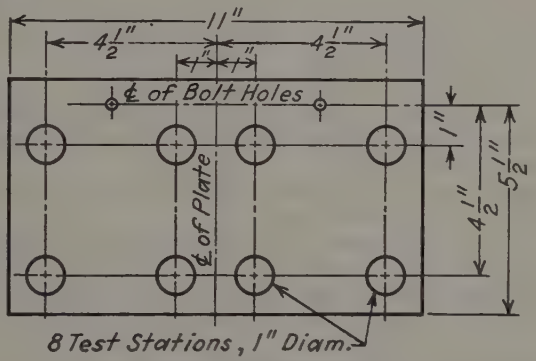


FIG. 2—MOTORCYCLE AND MOTOR-DRIVEN CYCLE LAMPS

Photometric Test—The illumination at each of the eight stations on the test plate shall be at least 0.5 ft-c. The ratio of maximum illumination to minimum illumination shall not exceed 30 to 1. The average of the two highest and the two lowest illumination values recorded at the eight test stations shall be taken as maximum and minimum values respectively.

Turn-Signal Units

SAE Recommended Practice

Report of Lighting Division approved February 1927 and last revised by Lighting Technical Committee September 1950.

Definition—A turn-signal unit is that part of the signal system by which is indicated the direction in which the turn will be made.

Turn-signal units are divided into two groups, Class A and Class B. Class A turn-signal units may be used on any vehicle.

Class B turn-signal units may be used on any passenger car; and on any other vehicle where the distance from the center of the steering wheel to the extreme left side of the vehicle is less than 24 in. and where the distance from the center of the steering wheel to the extreme rear end of the vehicle or combination of vehicles is less than 14 ft; except that Class B units should not be used on truck tractors, house trailers, semi-trailers, and trailers with four or more wheels.

Class A and Class B turn-signal units are divided into three types: Type I signal units are lamps which indicate a change in direction by giving flashing warning lights on the side toward which the turn will be made.

Type II signal units are lamps which indicate a change in direction by means of illuminated flashing arrow heads or other similar means on the side toward which the turn will be made.

Type III signal units include all types of semaphore signals.

General Requirements—Class A, Type I signal units should have at least 12 sq in. of effective illuminated area. In Class A and Class B, Type I units, the exposed illuminated area of the signal unit need have no arrow, word, letter, or other device intended to identify the signal.

A double-faced unit, when subjected to external light rays from either in front or behind, at any and all angles, should not give the appearance of being internally illuminated to such an extent as to be confusing.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles. A range shall be included for observation of the signal at a distance of at least 100 ft under normal sunlight and darkness.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Color Test—The turn-signal indication should be red or amber to the rear and white to amber to the front of the vehicle. See SAE Standard on Color Specification for Electric Lamps.

Photometric Test—For Class A and Class B, Type I signal units only, see Section L of SAE Standard on Lighting Equipment for Motor Vehicles.

All beam candlepower measurements should be made with the incandescent filament of the signal lamp at least 10 ft from the photometer screen for Class A, Type I signals and at least 4 ft from the photometer screen for Class B, Type I signals. The lamp axis should be taken as the horizontal line through the filament parallel to what would be the longitudinal axis of the vehicle if the lamp were mounted in its normal position on the vehicle.

Understandability and Visibility Test—This test is for Class A and Class B, Type II and Type III signal units only.

The significance of the signal as indicating a turn either to the left or to the right should be capable of being recognized and being understood in normal sunlight and at night from straight ahead or back through the lamp axis as follows:

Left signal at 100 ft	5°U—0° and 5°L H—0° and 5°L 5°D—0° and 5°L	Left signal at 35 ft	5°U—0° and 20°L H—0° and 20°L 5°D—0° and 20°L
Right signal at 100 ft	5°U—0° and 5°R H—0° and 5°R 5°D—0° and 5°R	Right signal at 35 ft	5°U—0° and 20°R H—0° and 20°R 5°D—0° and 20°R

To determine their understandability, the signals should be set up and operated while viewed by at least seven observers with normal vision. At least four of the observers must be in agreement on the satisfactory operation of the signal.

Installation Recommendations—(These recommendations are not a part of the test specifications.)

Each vehicle that is capable of being operated separately should be equipped with signal units giving signals to the front and to the rear and so arranged that front and rear signals may be given on the side toward which the turn is to be made. Dual front and rear signals may be used on such vehicles. Each vehicle not capable of being operated separately, except where Type III semaphore signal units are used, should be equipped with rear signal units. Signal units on a train of vehicles should be arranged so that all signal units on the combination on the side toward which the turn is to be made, or only the unit or units of the foremost vehicle and the unit on the rearmost vehicle on the side toward which the turn is to be made, may be actuated simultaneously, as required by law or regulation.

Signal units on the front and on the rear should be spaced as far apart laterally as practical but not less than 3 ft for Class A or 2 ft for Class B units, except that the spacing for motorcycles and motor-driven cycles should not be less than 1 ft.

The location of the front signal units should be such that they can be clearly distinguished when the headlamps are lighted on the lower beam.

Signal units should be mounted as high as practical for Class A, Type I units.

Signal units should be mounted so that the signal to the front is visible from directly in front to 45 deg to the left for the left unit and from directly in front to 45 deg to the right for the right unit, and so that the signal to the rear is visible from directly to the rear to 45 deg to the left for the left unit and from directly to the rear to 45 deg to the right for the right unit; except that, on other than the rearmost vehicle, the signal to the rear should be visible from not less than 10 deg to the left

to 45 deg to the left for the left signal and from not less than 10 deg to the right to 45 deg to the right for the right signal.

Within the horizontal angles specified, all signals should be visible from 10 deg above to 10 deg below the horizontal.

Class A and Class B, Type II signals which incorporate an illuminated arrow, or other similar means, should be designed so that the surface of the indicating means is free from cavities which will collect dust, ice, or similar foreign particles.

Where flashing is provided, turn-signal units should flash no slower than 60 nor faster than 120 times per min under average operating conditions. The "on" period of the flashes should be long enough to permit the bulb filaments to come up to full brightness.

If any turn-signal unit is not readily visible to the operator of the vehicle, there should be a visible or audible means of giving a clear and unmistakable indication to the driver that the signal system is turned "on".

Turn-Signal Operating Units

SAE Recommended Practice

Report of Lighting Technical Committee approved September 1950.

Definition—An operating unit is that part of a turn-signal system by which the operator of a vehicle causes the signal units to function.

Operating units are divided into two groups, Class A and Class B. Class A turn-signal operating units may be used on any vehicle.

Class B turn-signal operating units may be used on any passenger car; and on any other vehicles where the distance from the center of the steering wheel to the extreme left side of the vehicle is less than 24 in. and where the distance from the center of the steering wheel to the extreme rear end of the vehicle or combination of vehicles is less than 14 ft, except that Class B operating units should not be used on truck tractors.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Durability Test—The operating unit should be tested under conditions (normal bulb load, flasher, pilot) simulating its usage on a vehicle. When the operating unit is provided with a self-cancelling mechanism, the test equipment should be arranged so that the self-cancelling mechanism will cause the operating unit to be turned "off" in its normal operating manner. The test should be made at a rate not to exceed 25 complete cpm, except that when a flasher is used, the rate should be slow enough to permit the signal bulbs to flash at least twice for each operation of the unit. During the test, the unit should be operated from a fully charged 100 amp-hr battery connected to a 10-amp constant-current charger.

Test requirements are as follows:

Class A operating units	175,000 complete cycles
Class B operating units	50,000 complete cycles

If the test unit is still operative after completion of the test (except that bulbs may be replaced during the period of test), it should be considered satisfactory.

Clearance, Side-Marker, Identification, and Parking Lamps

SAE Standard

Report of Lighting Division approved January 1937 and last revised by Lighting Technical Committee September 1950.

Definitions—Clearance lamps are lamps on the left and right side of the front and rear of a vehicle which show to the front and rear, respectively, to mark the extreme sides of the vehicle.

Side-marker lamps are lamps on the left and right sides near the front and rear of a vehicle, which show to the side, to mark the sides of the vehicle.

A combination clearance and side-marker lamp is a single lamp which fulfills the requirements of both a clearance lamp and a side-marker lamp.

Identification lamps are groups of three lights in a horizontal row, spaced not less than 6 nor more than 12 in. apart, measured from center to center of lens, mounted near the top of the center of the front and rear of the permanent structure of the vehicle, which show to the front and the rear, respectively, to identify a certain type of vehicle.

Parking lamps, whether separate or in combination with other lamps, are lamps on the left only or on both the left and right of the vehicle which show to the front or rear, or both, and are primarily intended to mark the vehicle when parked.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Color Test—Front clearance lamps, front and intermediate side-marker lamps, and front identification lamps should be amber. Rear clearance lamps, rear side-marker lamps, and rear identification lamps should be red. The color of the parking lamp, when showing to the front, should be white to amber. When showing to the rear, the color should be red. See SAE Standard on Color Specification for Electric Lamps.

Photometric Test—See Section L of SAE Standard on Lighting Equipment for Motor Vehicles.

All beam candlepower measurements shall be made with a bar photometer, or equivalent, with the center of light at a distance of at least 4 ft from the photometer screen. In measuring distances and angles, the incandescent filament shall be taken as the center of light. The axis of a parking, clearance, or identification lamp shall be taken as the line through the center of the light source and parallel to the longitudinal axis of the vehicle. The axis of a side-marker lamp shall be taken as the line through the light source and normal to the vertical plane through the longitudinal axis of the vehicle.

Back-Up Lamps

SAE Recommended Practice

Report of Lighting Technical Committee approved August 1947 and last revised December 1948.

Definition—Back-up lamps may be used to provide illumination behind the vehicle when the vehicle is in reverse motion.

Means should be provided either to turn the back-up lamps off automatically when the vehicle is in forward motion, or to indicate to the driver by visible or audible means that back-up lamps are on.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric-Test Points—See Section J of SAE Standard on Lighting Equipment for Motor Vehicles.

Photometric Test—Photometric tests shall be made with the photometer at a distance of not less than 15 ft from the lamp.

The light source shall be located at the designed position as specified by the manufacturer.

The light from a single lamp should meet the following photometric specification when aimed in accordance with the manufacturer's service instructions:

H and above	300 cp maximum
1½ D and above	800 cp maximum

The line on the test screen formed by the intersection of the horizontal plane through the light source is designated as H.

Reflex Reflectors

SAE Recommended Practice

Report of Lighting Division approved January 1931 and last revised May 1942.

Scope—This specification applies to the performance of reflex reflectors used to supplement lamps on the motor vehicle. It covers Class A and Class B reflex reflectors as defined below.

The purpose of this specification is to provide a practical laboratory test procedure that will insure a satisfactory indication from a reflex reflector at the distances prescribed when viewed from the driver's position behind the headlamps.

Definition—Reflex reflectors are devices used on a motor vehicle to give an indication to an approaching driver by reflected light from the lamps on the approaching vehicle. A Class A reflex reflector shall be visible at night from all distances within 500 ft to 50 ft. A Class B reflex reflector shall be visible from all distances between 300 ft and 50 ft.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles. The vibration test shall be made on reflex reflectors which are used separately and not as part of a rear lamp.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles. The corrosion test shall be made on reflex reflectors which are used separately and not as part of a rear lamp.

Color Test—See SAE Standard on Color Specification for Electric Lamps.

Setup for Testing—In the laboratory, the reflex reflector to be tested shall be located at a distance of 100 ft from a single headlamp. The incandescent lamp shall be operated at approximately normal efficiency. The beam candlepower projected on the reflex reflector shall be 10,000, which may be obtained by using a commercial headlamp to which a suitable mask has been fitted. A calibrated standard shall be located adjacent to the reflex reflector and arranged so that the observer can readily vary the candlepower from this standard to make its intensity duplicate that of the reflex reflector under test. The calibrated standard shall be designed to avoid back reflection in the direction of the observer. The calibrated standard shall be of such size and emit light of such color and so diffused that, when viewed by the observer through a reducing glass if necessary, the candlepower from the two units can be readily and accurately compared. For a reflex reflector used as part of a rear lamp, observations shall be made from a point 7 in. above the headlamp center and approximately in the plane of the headlamp face. For a reflex reflector used separately as an independent unit and not as part of a rear lamp, observations shall be made from a point 7 in. above the headlamp center and an additional set of observations from a point 42 in. above the headlamp center. The axis of the reflex reflector shall be taken as the horizontal line through the center of the reflex area and parallel to what would be the longitudinal axis of the vehicle if the lamp were mounted in its normal position on the vehicle.

Photometric Test

Visual Test—For Class A reflex reflectors, measurements shall be made under the following conditions of observation: with an angle between a line from the zone of measurement to the unit and a line from the projector to the unit of ⅓ deg and 2 deg; with the plane of the unit perpendicular to the line from the projector to the unit; with the unit rotated from 10 deg up to 10 deg down, from 20 deg left to 20 deg right, and from 30 deg left to 30 deg right.

Photoelectric Test—Alternate test methods that employ photoelectric cells and give equivalent results will be acceptable.

The observed values, given in terms of cp per ft-c incident, shall not be less than those shown in Table 1.

TABLE 1—*Minimum Cp for Class A Reflex Reflectors*

OBSERVATION, DEG	0 DEG	10 DEG FORWARD TO BACK	20 DEG LEFT TO RIGHT	30 DEG LEFT TO RIGHT
⅓[a]	1.00	0.70	0.70	0.40
2[b]	0.05	0.05	0.05	0.03

[a] 7 in. at 100 ft.
[b] 42 in. at 100 ft.

For Class B reflex reflectors, measurements shall be made under the following conditions of observation: with an angle between a line from the zone of measurement to the unit and a line from the projector to the unit of ⅓ deg; with the plane of the unit perpendicular to the line from the projector to the unit; with the unit rotated from 10 deg up to 10 deg down and from 20 deg left to 20 deg right.

The observed values, given in terms of cp per ft-c incident, shall not be less than those shown in Table 2.

TABLE 2—*Minimum Cp for Class B Reflex Reflectors*

OBSERVATION, DEG	0 DEG	10 DEG FORWARD TO BACK	20 DEG LEFT TO RIGHT
⅓[a]	0.05	0.03	0.03

[a] 7 in. at 100 ft.

In the case of reflex reflectors designed and intended for mounting on opposite sides of the car, the individual units shall have the values specified above on the axis, at 10 deg above and at 10 deg below, and the unit intended for mounting on the left shall meet the 20 deg left value and the right the 20 deg right value.

The uncolored reflection from the front surface shall be such that, at any of the test locations, the color of the signal shall not be obliterated.

School-Bus Warning-Signal Lamps

SAE Recommended Practice

Report of Lighting Technical Committee approved December 1948 and last revised by Lighting Technical Committee September 1950.

Definition—School-bus warning-signal lamps are alternately flashing lamps at the same horizontal level intended to identify a vehicle as a school bus and to inform other users of the highway that such vehicle is about to stop, or is stopped, to take on on or discharge school children.

General Requirements—School-bus warning lamps should have at least 12 sq in. of effective illuminated area. The exposed illuminated area of the lamp need have no word, letter, nor other device intended to identify the signal.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Lamp Bulbs—See Section C of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Color Test—See SAE Standard on Color Specification for Electric Lamps.

Photometric Test—See Section L of SAE Standard on Lighting Equipment for Motor Vehicles.

All beam candlepower measurements shall be made with a bar photometer, or equivalent, with the filament of the lamp at a distance of at least 10 ft from the photometer screen. The lamp axis shall be taken as the horizontal line through the light source parallel to what would be the longitudinal axis of the vehicle if the lamp were mounted in its normal position on the vehicle.

General Warning-Signal System Recommendations—(These general school-bus warning-signal system recommendations are not a part of the test specifications.)

Each bus should be equipped with two alternately flashing red lamps on the rear and two alternately flashing red or amber lamps on the front.

Front and rear signal lamps should be spaced as far apart laterally as practical, but in no case should the spacing be less than 3 ft. The location of front signal lamps should be such that they can be clearly distinguished when the headlamps are lighted on the lower beam.

Warning-signal lamps should be mounted as high as possible, but in no case should the center of the lamp be lower than 6 in. below the bottom line of the windows.

Vision of front signals to the front and of rear signals to the rear should be unobstructed by any part of the vehicle 10 deg above to 10 deg below the horizontal and from 20 deg to the right to 20 deg to the left of the centerline of the vehicle.

School-bus warning-signal lamps should flash no slower than 60 nor faster than 120 times per min under normal operating conditions. The "on" period of the flasher should be long enough to permit the bulb filament to come up to full brightness.

There should be a visible or audible means of giving a clear and unmistakable indication to the driver when the signal lamps are turned "on".

The signal lamps should be controlled by an automatic door-operated switch and by a spring-return manual switch. In addition, a manually operated master switch should be provided to disconnect the complete signal system.

Electric Emergency Lanterns

SAE Recommended Practice

Report of Lighting Division approved January 1937 and last revised by Lighting Technical Committee January 1949.

Definition—An emergency electric lantern is a device capable of providing and displaying a warning light, either flashed[1] or steady-burning, indicating to the driver of an approaching motor vehicle that a hazard is present and that he should proceed with caution.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilites—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

Moisture Test—See Section F of SAE Standard on Lighting Equipment for Motor Vehicles.

Dust Test—See Section G of SAE Standard on Lighting Equipment for Motor Vehicles.

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

The above tests shall be made before the reliability and photometric or visibility tests.[2]

Color Test—The indication of lanterns using incandescent

[1] Flashing greatly increases the attracting power of an emergency electric lantern and should be encouraged as a means for identifying the presence of a hazard.

[2] The optical specifications are based upon the assumption that suitable regulations covering the removal or recharging of the electrical supply will be made and enforced by the proper authorities.

bulbs shall be red. See SAE Standard on Color Specification for Electric Lamps.

Reliability Test—In the case of lanterns which can be turned on or off at will, a sample unit shall be set up in complete form and operated for 1000 cycles, using the operating unit or switch submitted with the device as a part thereof. This test shall be made at a rate not to exceed 50 times per min. In the case of flashing units the rate shall be slow enough to permit the unit to flash at least twice for each operation of the switch.

When this test is completed, the operating unit shall not show any evidence of material physical weakness, excessive wear, or high resistance.

The lantern shall be turned on for a period of 12 hr. During this test, the "on" period for the flasher, if one is provided, shall be long enough at all times to permit the source to come up to required visibility or full brightness. The rate of flashing during the test shall not be less than 60 or more than 150 cpm, except for gaseous discharge lamps in which the rate of flashing shall not be more than 200 cpm.

If during these tests the flasher (if one is provided) continues to function as specified, and if after these tests the lantern with the battery used in the tests meets all optical requirements, the lantern shall be considered satisfactory from the reliability standpoint.

Photometric Test—This test is for emergency lanterns with a continuous beam or long "on"-period flash.

All beam candlepower measurements shall be made with the the center of light at a distance of at least 4 ft from the photometer screen. In measuring distances and angles, the source shall be taken as the center of light. The lamp axis shall be taken as the horizontal line through the light source parallel to the mounting surface as indicated by the manufacturer.

Directly to the front and rear of the lanterns on the axis, the light shall have an intensity of at least 0.50 cp.

To the front and rear of the lantern, from 2½ deg up to 2½ deg down and from 20 deg left to 20 deg right, there shall be at least 0.30 cp.

To the front and rear of the lantern, from 5 deg up to 5 deg down and from 30 deg left to 30 deg right, there shall be at least 0.10 cp.

Visibility Test—This test is for emegency lanterns with a short "on"-period flash.[3]

In measuring distances and angles, the source shall be taken as the center of light.

To the front and rear of the lantern, from 2½ deg up to 2½ deg down and from 20 deg left to 20 deg right, the signal shall be visible from a distance of at least 1000 ft after dark.

To the front and rear of the lantern, from 5 deg up to 5 deg down and from 30 deg left to 30 deg right, the signal shall be visible from a distance of at least 750 ft.

[3] When the "on" period of a flasher is extremely short as in the case of the gaseous discharge lamp operated through a condenser discharge, the candlepower alone without the duration time of discharge is meaningless; therefore, a visibility test is preferable.

Liquid-Burning Emergency Flares

SAE Recommended Practice

Report of Lighting Technical Committee approved January 1949.

Definition—A liquid-burning emergency flare is a device capable of providing and displaying a warning light, indicating to the driver of an approaching motor vehicle that a hazard is present and that he should proceed with caution.

Samples for Test—See Section B of SAE Standard on Lighting Equipment for Motor Vehicles.

Laboratory Facilities—See Section D of SAE Standard on Lighting Equipment for Motor Vehicles.

Vibration Test—See Section E of SAE Standard on Lighting Equipment for Motor Vehicles.

(Flares shall be provided in sets of three contained in a metal rack or metal box which can be securely mounted on the vibration machine.)

Corrosion Test—See Section H of SAE Standard on Lighting Equipment for Motor Vehicles.

Instructions—The manufacturer shall furnish with each set of flares submitted for laboratory test printed instructions as to wick adjustment, maximum filling level, the method of installation, and such other details as the manufacturer may deem necessary in order that the user of these flares may be able to operate them at their maximum efficiency.

Weatherproof Test—The flares used for these tests shall be filled with kerosene to the level recommended in the manufacturer's instructions and shall have the wicks adjusted as recommended by the manufacturer.

After a preheating period of 5 min in still air, a sample flare, lighted and mounted in its normal operating position on a table rotating at 4 rpm and in a wind of approximately 2 mph, shall be subjected to a water spray from an adjustable, solid-cone nozzle (such as the ordinary garden-hose spray nozzle) set so

that the nozzle outlet is 8 to 12 ft horizontally from the sample and 1 to 3 ft vertically above the sample, with the nozzle axis pointing upward at an angle of approximately 45 deg with the horizontal, and with the water striking the sample at an angle of approximately 45 deg with the horizontal in a downward direction.

Under the conditions specified above and with a water pressure of 5 to 7½ psi at the nozzle, the rate of precipitation at the location of the sample shall be adjusted to 0.10 in. per min. The sample shall be introduced gradually into the spray and after being placed in the test location shall continue to operate under these conditions for 15 min. This test shall be made on each of the three flares constituting a set, and two out of three shall pass the test.

With the rate of rotation and the wind condition the same as described above, the water pressure shall be further increased to a value of 18 to 20 psi and the sample moved farther from the nozzle, if necessary, to a location giving a precipitation of 0.01 in. per min striking the sample at approximately 45 deg with the horizontal. Under these conditions, the sample shall continue to operate for 1 hr and 30 min. This test shall be made on each of the three flares constituting a set, and two out of the three shall pass the test.

Note: Solid-cone spray nozzles, operating at 5 to 7½ psi, give a spray consisting of relatively large drops when set so that the center of the stream at the flare shows 0.10 in. per min precipitation. At higher pressures, the drops are smaller. These conditions are comparable to actual rain.

Reliability, Stability, and Life Tests—The flares used for these tests shall be filled with kerosene to the level recommended by the manufacturer and shall have the wicks adjusted in accordance with the manufacturer's instructions.

A flare that is nearly empty of fuel shall be lighted, placed on a horizontal concrete surface similar to a pavement, and allowed to burn in still air for a preheating period of 5 min. It shall then be placed suddenly in an air stream of 40 mph and withdrawn. After rotating through approximately 45 deg, it shall again be placed in the air stream and withdrawn. It shall be rotated again through an additional 45 deg approximately and placed in the air stream and withdrawn a third time. If the flame is extinguished or if the flare slides or is overturned by the wind on any one of these three operations, the sample shall have failed to pass the test. The test shall then be repeated on each of the other two samples constituting a set, and two out of the three shall pass the test.

A flare, lighted and mounted in its normal operating position, rotating about its vertical axis at 4 rpm, shall be subjected to a horizontal current of air having a velocity the equivalent of wind at 40 mph. This test shall continue for 15 min and the flare shall remain lighted throughout the entire 15-min period.

Upon completion of the above test, the flare shall, while lighted and rotated as specified above, be subjected to a horizontal current of air having a velocity of 5 mph. The total uninterrupted burning time, including the first 15 min at 40 mph, shall be at least 12 hr. The flare shall not be refilled during test; there shall be no adjustment of wick.

The flare shall operate satisfactorily for a period of at least 2 hr in still air.

Photometric Test—A sample flare, when subjected to a wind velocity of 5 mph and 40 mph, respectively, shall produce a minimum of 0.10 cp in a horizontal direction.

Lamps for Aircraft Lighting

SAE Recommended Practice

Report of Lighting Division approved January 1946 and last revised by Lighting Technical Committee January 1950. This SAE Recommended Practice conforms with a corresponding IES Recommended Practice.

[The lamps shown are those recommended for the service indicated. This list is not intended to be a catalog and hence does not include many types of lamps now in use.]

TABLE 1—*Services and Properties of Lamps for Aircraft Lighting*

LINE NO.	SERVICE	CIRCUIT VOLTS	LAMP NO.	ARMY-NAVY PART NO.	AMPS, WATTS, OR CP	BULB	BASE	FILAMENT	LIGHT CENTER LENGTH, IN.	MAX OVER-ALL LENGTH, IN.	DESIGN VOLTS	MAX AMPS AT DESIGN VOLTS	RATED AVG LAB LIFE,[a] HR	APPROX WEIGHT EACH, LB
1	Landing	6	4538	—	100 W	PAR-46	Sc. Term.	C-6	—	3⅜	5.4	—	25	0.92
2	Landing	12–16	4537	—	100 W	PAR-46	Sc. Term.	C-6	—	3⅜	13.0	—	25	0.92
3	Landing	12–16	4522	—	250 W	PAR-46	Sc. Term.	C-2V	—	3⅜	13.0	—	25	0.92
4	Landing	24–28	4523	AN3129–4523	250 W	PAR-46	Sc. Term.	C-13	—	3⅜	28.0	—	25	0.92
5	Landing	24–28	4560	AN3130–4560	600 W	PAR-64	Sc. Term.	C-13	—	4	28.0	—	25	2.00
6	Taxiing	24–28	4570	—	150 W	PAR-46	Sc. Term.	CC-6	—	4	28.0	5.8	300	0.92
7	Position	6–8	87	—	15 Cp	S-8	S. C. Bay.	C-2R	1⅛	2	6.75	2.04	300	0.021
8	Position	6–8	1506[c]	—	24 Cp	GG-10[c]	S. C. Index.	CC-6	—	2 3/16	6.4	3.48	300	0.019
9	Position	12–16	93	—	15 Cp	S-8	S. C. Bay.	C-2R	1⅛	2	12.8	1.15	500	0.021
10	Position	12–16	1512[c]	AN3122–1512	24 Cp	GG-10[c]	S. C. Index.	C-2R	—	2 3/16	12.8	1.6	300	0.019
11	Position	12–16	1143	—	32 Cp	RP-11	S. C. Bay.	C-2R	1¼	2¼	12.5	2.13	400	0.022
12	Position	12–16	1747	AN3133–1747	50 Cp	S-11	S. C. Bay.	C-2V	1¼	2⅜	12.5	3.6	300	0.022
13	Position	24–28	1524[c]	AN3122–1524	24 Cp	GG-10[c]	S. C. Index.	CC-6	—	2 3/16	28.0	0.83	300	0.019
14	Position	24–28	315[d]	—	32 Cp	S-8	S. C. Bay.	C-2V	1⅛	2	28.0	1.03	300	0.021
15	Position	24–28	311	AN3133–311	50 Cp	S-11	S. C. Bay.	C-2V	1¼	2⅜	28.0	1.55	300	0.021
16	Interior	6–8	63	—	3 Cp	G-6	S. C. Bay.	C-2R	¾	1 7/16	7.0	0.73	1000	0.012
17	Interior	6–8	81	—	6 Cp	G-6	S. C. Bay.	C-2R	¾	1 7/16	6.5	1.14	500	0.012
18	Interior	6–8	87	—	15 Cp	S-8	S. C. Bay.	C-2R	1⅛	2	6.75	2.04	300	0.021
19	Interior	6–8	1129	—	21 Cp	S-8	S. C. Bay.	C-2V	1¼	2	6.4	2.91	200	0.021
20	Interior	6–8	1725	—	50 Cp	S-11	S. C. Bay.	C-2V	1¼	2⅜	5.5	6.95	100	0.022
21	Interior	12–16	77	AN3141–77	3 Cp	G-5	S. C. Bay.	C-2V	1 1/16	1⅜	13.0	0.41	1000	0.012
22	Interior	12–16	89	AN3131–89	6 Cp	G-6	S. C. Bay.	C-2R	¾	1 7/16	13.0	0.63	750	0.012
23	Interior	12–16	1141	AN3124–1141	21 Cp	S-8	S. C. Bay.	C-2R	1¼	2	12.8	1.5	500	0.021
24	Interior	12–16	1141SB[c]	AN3124–SB1141	21 Cp	S-8	S. C. Bay.	C-2R	1¼	2	12.8	1.5	500	0.021
25	Interior	12–16	1747	AN3133–1747	50 Cp	S-11	S. C. Bay.	C-2V	1¼	2⅜	12.5	3.6	300	0.022
26	Interior	12–16	1747SB[c]	AN3133–SB1747	50 Cp	S-11	S. C. Bay.	C-2V	1¼	2⅜	12.5	3.6	300	0.023
27	Interior	24–28	301	AN3141–301	3 Cp	G-5	S. C. Bay.	C-2	1 1/16	1⅜	28.0	0.19	500	0.012
28	Interior	24–28	303	AN3131–303	6 Cp	G-6	S. C. Bay.	C-2	¾	1 7/16	28.0	0.34	500	0.012
29	Interior	24–28	307	AN3124–307	21 Cp	S-8	S. C. Bay.	C-2V	1⅛	2	28.0	0.75	300	0.021

(*Continued on next page.*)

TABLE 1—*Services and Properties of Lamps for Aircraft Lighting (Concluded)*

LINE NO.	SERVICE	CIRCUIT VOLTS	LAMP NO.	ARMY-NAVY PART NO.	AMPS, WATTS, OR CP	BULB	BASE	FILAMENT	LIGHT CENTER LENGTH, IN.	MAX OVER-ALL LENGTH, IN.	DESIGN VOLTS	MAX AMPS AT DESIGN VOLTS	RATED AVG LAB LIFE,[a] HR.	APPROX WEIGHT EACH, LB
30	Interior	24–28	307SB[e]	AN3124–SB307	21 Cp	S-8	S. C. Bay.	C-2V	1⅛	2	28.0	0.75	300	0.021
31	Interior	24–28	311	AN3133–311	50 Cp	S-11	S. C. Bay.	C-2V	1¼	2⅜	28.0	1.55	300	0.021
32	Interior	24–28	311SB[e]	AN3133–SB311	50 Cp	S-11	S. C. Bay.	C-2V	1¼	2⅜	28.0	1.55	300	0.022
33	Interior	24–28	1385[e]	—	20 W	R-12[e]	S. C. Bay.	CC-8	—	2⅝	28.0	0.79	300	0.026
34	Interior[b]	—	—	—	6 W[g]	T-5	Min. Bipin	—	—	9	—	—	—	—
35	Interior[b]	—	—	—	8 W[g]	T-5	Min. Bipin	—	—	12	—	—	—	—
36	Interior[b]	—	—	—	14 W[g]	T-12	Med. Bipin	—	—	15	—	—	—	—
37	Interior[b]	—	—	—	15 W[g]	T-8	Med. Bipin	—	—	18	—	—	—	—
38	Interior[b]	—	—	—	30 W[g]	T-8	Med. Bipin	—	—	36	—	—	—	—
39	Indicator or	6	328	AN3140–328	0.20 A	T-1¾	Mid. Flange	C-6	⅜	⅝	6.0	0.22	500	0.0012
40	Instrument	6–8	44	—	0.25 A	T-3¼	Min. Bay.	C-2R	¾	1 13/16	6.3	0.275	3000	0.006
41		6–8	63	—	3 Cp	G-6	S. C. Bay.	C-2R	¾	1 7/16	7.0	0.73	1000	0.012
42		6–8	81	—	6 Cp	G-6	S. C. Bay	C-2R	¾	1 7/16	6.5	1.14	500	0.012
43	Indicator or	14	330	—	0.08 A	T-1¾	Mid. Flange	C-2V	⅜	⅝	14.0	0.09	350	0.0012
44	Instrument	12–16	77	AN3141–77	3 Cp	G-5	S. C. Bay.	C-2V	11/16	1⅜	13.0	0.41	1000	0.012
45		12–16	89	AN3131–89	6 Cp	G-6	S. C. Bay.	C-2R	¾	1 7/16	13.0	0.63	750	0.012
46		12–16	1816[f]	AN3121–1816	0.33 A	T-3¼	Min. Bay.	C-2V	⅝	1 3/16	13.0	0.38	1000	0.006
47	Instrument	12–16	F3RP12-360BL	—	3 W	RP-12	D. C. Index.	—	—	2 9/16	[h]	—	200	0.026
48	Indicator or	24–28	327	AN3140–327	0.04 A	T-1¾	Mid. Flange	C-21	⅜	⅝	28.0	0.048	350	0.0012
49	Instrument	24–28	301	AN3141–301	3 Cp	G-5	S. C. Bay.	C-2	11/16	1⅜	28.0	0.19	500	0.012
50		24–28	303	AN3131–303	6 Cp	G-6	S. C. Bay.	C-2	¾	1 7/16	28.0	0.34	500	0.012
51		24–28	313[f]	AN3121–313	0.17 A	T-3¼	Min. Bay.	C-2	⅝	1 3/16	28.0	0.19	500	0.006
52	Instrument	24–28	F5000	AN3125–F5000	4 W	RP-12	D. C. Index.	—	—	2 9/16	[i]	—	200	0.026
53	Instrument	24–28	F2T6/BL	—	2 W	T-6	D. C. Index.	—	—	2⅜	[i]	—	200	0.022
54	Signalling	12–16	4500	AN3126–4500	6.6 A	PAR-36	Sc. Term.	5C-8	—	2⅝	13.0	—	50	0.52
55	Signalling	24–28	4501	AN3126–4501	5.3 A	PAR-36	Sc. Term.	4CC-8	—	2⅝	26.0	—	50	0.52

[a] Under specified test conditions.
[b] Fluorescent lamp to be used with auxiliary of proper design; does not operate satisfactorily over the temperature range required for military aircraft.
[c] Reflectorized bulb.
[d] For horizontal burning only.
[e] Silvered bowl.
[f] Recommended only for intermittent use.
[g] Soft white color.
[h] For operation with resistance ballast on 12–16 v direct-current circuits.
[i] For operation with resistance ballast on 24–48 v direct-current circuits.

Lamps for Airdrome and Airway Lighting

SAE Recommended Practice

Report of Lighting Division approved January 1946 and last revised by Lighting Technical Committee January 1950. This SAE Recommended Practice conforms with a corresponding IES Recommended Practice.

[The lamps shown are those recommended for the service indicated. This list is not intended to be a catalog and hence does not include many types of lamps now in use.]

TABLE 1—*Services and Properties of Lamps for Airdrome and Airway Lighting*

LINE NO.	SERVICE	VOLTS OR AMPS	WATTS OR LUMENS	BULB	BASE	FILAMENT	LIGHT CENTER LENGTH, IN.	MAX OVER-ALL LENGTH, IN.	APPROX LUMENS	RATED AVERAGE LAB LIFE,[a] HR
1	Runway, Threshold, High Intensity	6.6 A	200 W	T-14	Med. Pref.	C-13	2 3/16	5 3/4	—	75
2	Runway, Threshold, High Intensity	115 V[d]	500 W	T-20	Med. Pref.	C-13D	2 3/16	5 3/4	13000	25
3	Approach, High Intensity	12½ V	250 W	PAR-56	2 Cont. Lugs	C-6	—	5¼	—	100
4	Approach, High Intensity	115 V	400 W	PAR-56	2 Cont. Lugs	CC-13	—	5¼	—	100
5	Approach, High Intensity	115 V[d]	5000 W	T-64	Mog. Bipost	C-13	6½	13 3/8	164000	75
6	Elevated Strip, Runway, Threshold, Taxiway	6.6 A	30 W	T-10	Med. Pref.	C-2V	1½	3 15/16	450	1000
7	Elevated Strip, Runway, Threshold, Taxiway	115 V[d]	40 W	T-10	Med. Pref.	CC-2V	1½	3 15/16	425	1000
8	Elevated Strip, Runway, Threshold, Taxiway	6.6 A	45 W	T-10	Med. Pref.	C-2V	1½	3 15/16	740	1000
9	Elevated Strip, Runway, Threshold, Taxiway	115 V[d]	100 W	T-10	Med. Pref.	CC-2V	1½	3 15/16	1225	1000
10	Boundary, Wind Tee[b]	115 V[d]	25 W	A-19	Med. Sc.	C-9	2½	3 15/16	260	1000
11	Obstruction[b]	115 V[d,e]	50 W	A-19	Med. Sc.	C-9	2½	3 15/16	550	1000
12	Obstruction[b]	115 V[d]	67 W	A-21	Med. Sc.	C-9	2 7/16	4 7/16	685	3000
13	Obstruction[c]	115 V[d]	111 W	A-21	Med. Sc.	C-9	2 7/16	4 7/16	1300	3000
14	Runway (Low Intensity), Boundary, Taxiway	115 V[d]	40 W	A-21	Med. Pref.	CC-2V	2¾	5 5/16	370	2000
15	Runway (Low Intensity), Boundary, Taxiway	6.6 A	325 L	A-21	Med. Pref.	C-8	2¾	5 5/16	320	2000
16	Range, Runway, Threshold (Low Intensity)	115 V[d]	100 W	A-21	Med. Pref.	CC-2V	2¾	5 5/16	1170	2000
17	Range, Runway, Threshold (Low Intensity)	6.6 A	1020 L	A-21	Med. Pref.	C-8	2¾	5 5/16	1000	2000
18	Beacon (Airdrome, Airway, Hazard, Landmark)	30 V	500 W	T-20	Med. Bipost	C-13B	3	7½	10000	500
19	Beacon (Airdrome, Airway, Hazard, Landmark)	30 V	1000 W	T-20	Mog. Bipost	C-13	4	9½	25500	500
20	Beacon (Airdrome, Airway, Hazard, Landmark)	115 V[d]	1000 W	T-20	Mog. Bipost	C-13	4	9½	20500	500
21	Beacon (Airdrome, Airway, Course Light, Hazard, Landmark)	115 V[d]	500 W	T-20	Med. Bipost	C-13B	3	7½	9250	500
22	Beacon (Airdrome)[b]	6 V	100 W	PAR-56	Sc. Term.	C-6	—	4½	—	500
23	Beacon (Obstruction Marker)	115 V[d]	230 W	PS-30	Mog. Pref.	C-9	5 1/16	8¾	3600	3000
24	Beacon (Identification, Obstruction Marker)	115 V[d]	620 W	PS-40	Mog. Pref.	C-7A	5 11/16	10 1/16	10800	3000
25	Floodlight (Landing Area or Runway)	32 V	1500 W	T-24	Mog. Bipost	C-13B	4	10½	42000	100
26	Floodlight (Landing Area or Runway)	32 V	3000 W	T-32	Mog. Bipost	C-13B	5¾	14	88500	100
27	Ceiling Projector	12 V	420 W	G-25	Mog. Pref.	C-2V	1 11/16	5 3/16	10500	100
28	Ceiling Projector	[f]	900 W	T-2	Sleeve	—	—	3¼[g]	65000	—
29	Landing-Direction Indicator (Tetrahedron)	115 V[d]	10 W	S-14	Med. Sc.	C-9	2½	3½	79	1500
30	Air Traffic Signal	6 V	50 W	T-8	D. C. Pref.	C-2V	1¼	3⅛	—	50
31	Air Traffic Signal	110 V	99 W	T-8	D. C. Pref.	CC-13B	1¼	3⅛	1800	50
32	Channel (Water)	[h]	6 W (Green)	T-5	Min. Bipin	—	—	9	—	—
33	Channel (Water)	[h]	15 W (Green)	T-8	Med. Bipin	—	—	18	900	—
34	Channel Threshold (Water)	[h]	6 W (Gold)	T-5	Min. Bipin	—	—	9	—	—
35	Channel Threshold (Water)	[h]	15 W (Gold)	T-8	Med. Bipin	—	—	18	375	—

[a] Under specified test conditions.
[b] Recommended for use on airports having nonscheduled operations.
[c] Recommended for use on airports having scheduled operations.
[d] Where necessary, 120- or 125-v lamps are available
[e] Vibration service lamp; operating position base up or base down only.
[f] Air-cooled, high-pressure mercury lamp to be used with auxiliary of proper design.
[g] Nominal length.
[h] Fluorescent lamp to be used with auxiliary of proper design.

Radio-Noise Suppressors

SAE Recommended Practice

Report of Electrical Equipment Technical Committee approved January 1951.

Flash-Over Specifications—*General*—Suppressor units shall have such characteristics that flash-over from the installed resistor to ground shall not occur at less than 30kv, or at a lower voltage than that which is obtained without the insertion of the resistor.

Suppressor elements must have sufficient flash-over distances to conform to section on Required Tests.

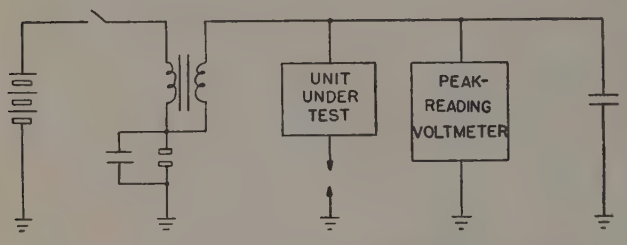


FIG. 1—CIRCUIT FOR RADIO-NOISE SUPPRESSOR TESTS

Required Constants—The circut in Fig. 1 will be used in all tests.

Circuit constants to be used are

Battery voltage: 7.0 v

Coil: Ford type 8EA; Auto-Lite type CE; Delco-Remy 1115380; or equivalent

Primary capacity: 0.21–0.24 microfarad

Cam angle: 27 deg

8-cylinder distributor operated at 800 rpm cam

Secondary capacity: 50 micro-microfarad ± 5%, as measured at secondary coil terminal

Secondary polarity: insulated terminal of gap is negative; AN-P-4 or equivalent

Temperature: 200 F

Relative humidity: 95%

Pressure: atmospheric

All leads to be held to a minimum length.

Required Tests—Suppressors in center tower of distributor, in leads, and on spark plugs must operate under the conditions specified in Required Constants for a period of 5 min without flash-over. External or internal flash-over may be detected by observing the characteristics of the gap discharge. With no flash-over, the spark is a thin gray discharge; but with flash-over, the discharge is a brilliant blue.

For suppressors in outer tower of distributor, assemble cap on distributor. Plug suppressor into tower adjacent to a cap hold-down spring. Operate under conditions specified in Required Constants. No flash-over shall occur during 5 min. A flash-over in this test may be observed as a miss or a brilliant blue spark.

Resistance Rating—Three values are specified. They are 5000 ohms ± 25%, 10000 ohms ± 25%, and 15000 ohms ± 25%.

Method of Measuring Resistance—All readings of resistance to be made with 5000 v across the resistor being tested. (This value will not agree with the resistance as read on a low-voltage bridge or ohmmeter.) These readings may be made with any device capable of giving a 5000-v pulse of short enough duration, and slow enough repetition rate, that the suppressor dissipation ration is not exceeded.

The maximum capacity across the terminals of the unit shall not exceed 1 micro-microfarad.

Reference Screen Room for the Inspection and Testing of Radio-Noise Suppression

SAE Standard

Report of Electrical Equipment Division approved January 1942.

[*This SAE Standard covers the size and the general construction and arrangement of the standard reference screen room for the inspection and testing of radio-noise suppression. It is supplemented by an SAE General Information giving optional construction details and arrangements.*]

The dimensions given in Fig. 1 provide for the largest size vehicles, including tanks, which it is anticipated will be subject to noise-suppression inspection.

All power lines for lighting and testing shall be brought inside the screen room at the point where screens are grounded. The outside and inside screens shall be insulated from each other and from ground at all other points.

Power lines shall be filtered by isolation transformer, filter, or both as may be required. All wire conduit shall be bonded to the inner screen every 2 ft.

The dimensions given shall be used for the engineering standard or pilot-car screen room. Corresponding dimensions of screen rooms for production inspection shall be worked out in accordance with the dimensions recommended for clearances and the size of the vehicles to be inspected.

The screens shall be constructed of No. 26 gage B&S (0.015 in.) copper sheathing, continuous seam soldered with noncorrosive flux. There shall be no metallic contact between the inside and outside layers (screens) or to ground except at the point of grounding.

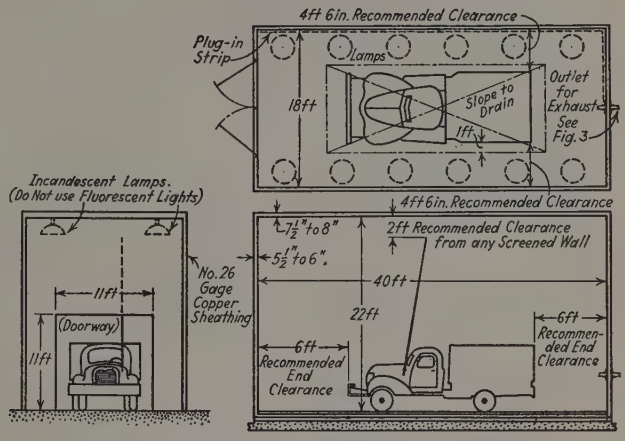


FIG. 1—REFERENCE SCREEN ROOM DIMENSIONS

Construction Details of Reference Screen Room for Radio-Noise Suppression Tests

SAE General Information

Report of Electrical Equipment Division approved January 1942.

The details and data included in this SAE General Information are optional in constructing individual reference screen rooms.

Constructional details other than those shown in Fig. 1 for light vehicles shall be the same as those shown in Fig. 2 for heavy vehicles.

The copper sheathing in the optional floor constructions shall be of No. 26 gage B&S (0.0159 in.), the sheathing or strips in each layer to be continuously seam soldered using nonmetallic flux. There shall be no metallic contact between the inside and outside layers or to ground except at the point of grounding.

(*Continued on next page.*)

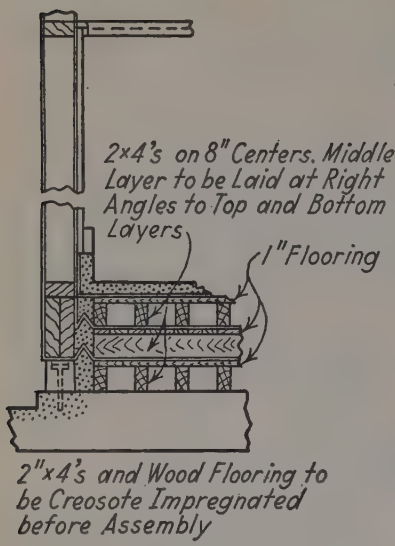

2×4's on 8" Centers. Middle Layer to be Laid at Right Angles to Top and Bottom Layers
1" Flooring
2"×4's and Wood Flooring to be Creosote Impregnated before Assembly

FIG. 1—OPTIONAL CONSTRUCTION FOR LIGHT VEHICLES

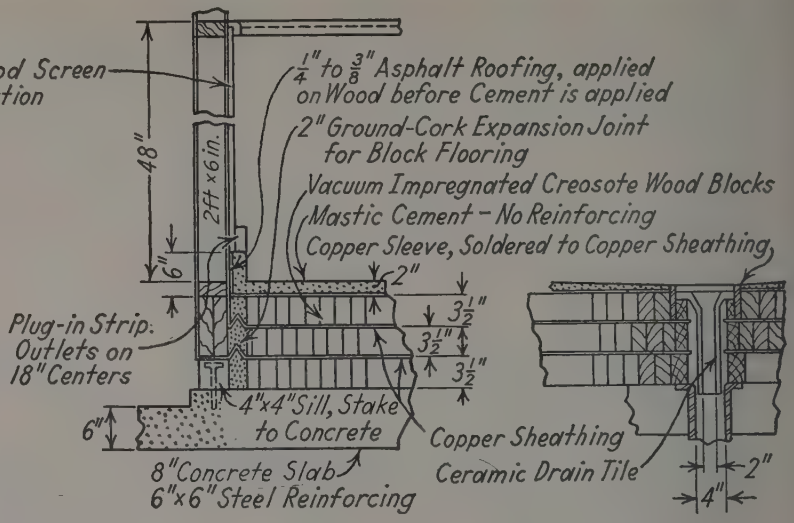


FIG. 2—CONSTRUCTION FOR HEAVY VEHICLES

The screening in the exhaust outlet shall be No. 19 gage copper wire, 8 mesh, tinned before weaving, and bonded to the copper sheathing.

The exhaust and power-line outlet, shown in Fig. 3, shall be bonded to the sheathing and grounded.

Refrigerator type of locking handles should be used on the inside of doors. Screen-room door detail is shown in Fig. 4.

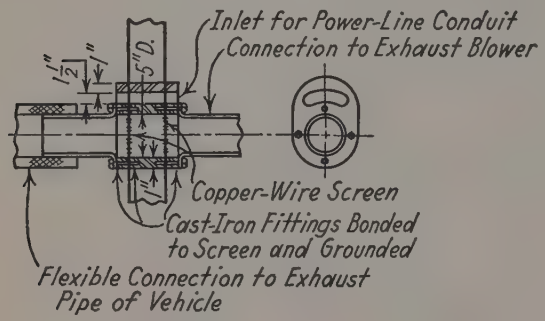


FIG. 3—EXHAUST AND POWER-LINE OUTLET

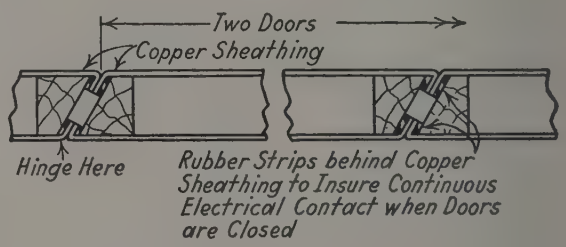

Two Doors
Copper Sheathing
Hinge Here
Rubber Strips behind Copper Sheathing to Insure Continuous Electrical Contact when Doors are Closed

FIG. 4—SCREEN-ROOM DOOR DETAIL

Engine Test Codes

SAE Standard

Report of Gasoline Engine Division approved March 1917. Diesel Engine Test Code last revised December 1941; Gasoline Engine Test Code last revised by Engine Technical Committee March 1951.

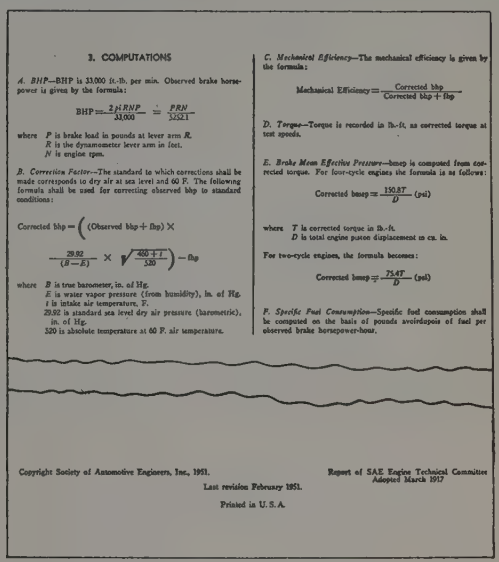
[The Diesel and Gasoline Engine Test Codes are intended for automotive engines. Table 1, which is part of this editor's note, identifies the test-code forms.

The Society sells the forms individually as well as in sets. Figs. 1–5 are small-scale reproductions of some of the gasoline test-code forms. Diesel forms are similar.

TABLE 1—*Designations of SAE Diesel and Gasoline Engine Test-Code Forms*

FORM	DIESEL CODE DESIGNATION	GASOLINE CODE DESIGNATION
Rules and Directions	DA	GA
Mechanical Information Sheet	DB1 and DB2	GB
Engine Log Sheet	DC	GC
Curve Sheets	DD1 (0–65 hp)	GD1 (0–95 hp, 400–2400 rpm)
	DD2 (0–130 hp)	GD2 (0–95 hp, 500–4000 rpm)
	DD3 (0–260 hp)	GD3 (0–190 hp, 400–2400 rpm)
	DD4 (blank ordinates)	GD4 (0–190 hp, 500–4000 rpm)
		GD5 (0–380 hp, 200–2400 rpm)
		GD6 (blank ordinates)

The 1951 revision of the Gasoline Engine Test Code differs from the previous version primarily in the formula for calculating corrected brake horsepower.]



3. COMPUTATIONS

A. BHP—BHP is 33,000 ft.-lb. per min. Observed brake horsepower is given by the formula:

$$BHP = \frac{2\pi RNP}{33{,}000} = \frac{PRN}{5252.1}$$

where P is brake load in pounds at lever arm R.
R is the dynamometer lever arm in feet.
N is engine rpm.

B. Correction Factor—The standard to which corrections shall be made corresponds to dry air at sea level and 60 F. The following formula shall be used for correcting observed bhp to standard conditions:

$$\text{Corrected bhp} = \left((\text{Observed bhp} + \text{fhp}) \times \frac{29.92}{(B - E)} \times \sqrt{\frac{460 + T}{520}} \right) - \text{fhp}$$

where B is true barometer, in. of Hg.
E is water vapor pressure (from humidity), in. of Hg.
t is intake air temperature, F.
29.92 is standard sea level dry air pressure (barometric), in. of Hg.
520 is absolute temperature at 60 F. air temperature.

C. Mechanical Efficiency—The mechanical efficiency is given by the formula:

$$\text{Mechanical Efficiency} = \frac{\text{Corrected bhp}}{\text{Corrected bhp} + \text{fhp}}$$

D. Torque—Torque is recorded in lb.-ft. as corrected torque at test speeds.

E. Brake Mean Effective Pressure—bmep is computed from corrected torque. For four-cycle engines the formula is as follows:

$$\text{Corrected bmep} = \frac{150.8T}{D} \text{ (psi)}$$

where T is corrected torque in lb.-ft.
D is total engine piston displacement in cu. in.

For two-cycle engines, the formula becomes:

$$\text{Corrected bmep} = \frac{75.4T}{D} \text{ (psi)}$$

F. Specific Fuel Consumption—Specific fuel consumption shall be computed on the basis of pounds avoirdupois of fuel per observed brake horsepower-hour.

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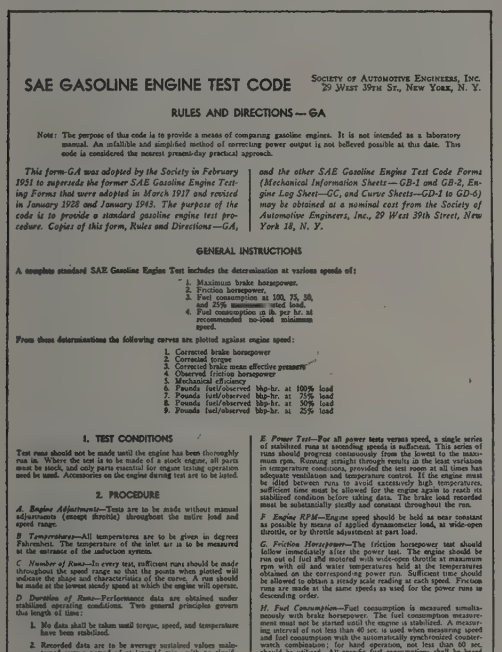
Report of SAE Engine Technical Committee Adopted March 1917

Last revision February 1951.

Printed in U. S. A.

FIG. 2—FORM GA, RULES AND DIRECTIONS (BACK OF FORM)



SAE GASOLINE ENGINE TEST CODE

Society of Automotive Engineers, Inc.
29 West 39th St., New York, N. Y.

RULES AND DIRECTIONS — GA

Note: The purpose of this code is to provide a means of comparing gasoline engines. It is not intended as a laboratory manual. An infallible and simplified method of correcting power output is not believed possible at this date. This code is considered the nearest present-day practical approach.

This form-GA was adopted by the Society in February 1921 to supersede the former SAE Gasoline Engine Testing Forms that were adopted in March 1917 and revised in January 1928 and January 1943. The purpose of the code is to provide a standard gasoline engine test procedure. Copies of this form, Rules and Directions—GA, and the other SAE Gasoline Engine Test Code Forms (Mechanical Information Sheets— GB-1 and GB-2, Engine Log Sheet—GC, and Curve Sheets—GD-1 to GD-6) may be obtained at a nominal cost from the Society of Automotive Engineers, Inc., 29 West 39th Street, New York 18, N. Y.

GENERAL INSTRUCTIONS

A complete standard SAE Gasoline Engine Test includes the determination at various speeds of:

1. Maximum brake horsepower.
2. Friction horsepower.
3. Fuel consumption at 100, 75, 50, and 25% maximum rated load.
4. Fuel consumption in lb. per hr. at recommended no-load minimum speed.

From these determinations the following curves are plotted against engine speed:

1. Corrected brake horsepower
2. Corrected torque
3. Corrected brake mean effective pressure
4. Observed friction horsepower
5. Mechanical efficiency
6. Pounds fuel/observed bhp-hr. at 100% load
7. Pounds fuel/observed bhp-hr. at 75% load
8. Pounds fuel/observed bhp-hr. at 50% load
9. Pounds fuel/observed bhp-hr. at 25% load

1. TEST CONDITIONS

Test runs should not be made until the engine has been thoroughly run in. Where the test is to be made of a stock engine, all parts must be stock, and only parts essential for engine testing operation need be used. Accessories on the engine during test are to be listed.

2. PROCEDURE

A. Engine Adjustments—Tests are to be made without manual adjustments (except throttle) throughout the entire load and speed range.

B. Temperatures—All temperatures are to be given in degrees Fahrenheit. The temperature of the inlet air is to be measured at the entrance of the induction system.

C. Number of Runs—In every test, sufficient runs should be made throughout the speed range so that the points when plotted will indicate the shape and characteristics of the curve. A run should be made at the lowest steady speed at which the engine will operate.

D. Duration of Runs—Performance data are obtained under stabilized operating conditions. Two general principles govern the length of time:

1. No data shall be taken until torque, speed, and temperature have been stabilized.
2. Recorded data are to be average sustained values maintained over a period of at least ½ min., with no significant change during that time.

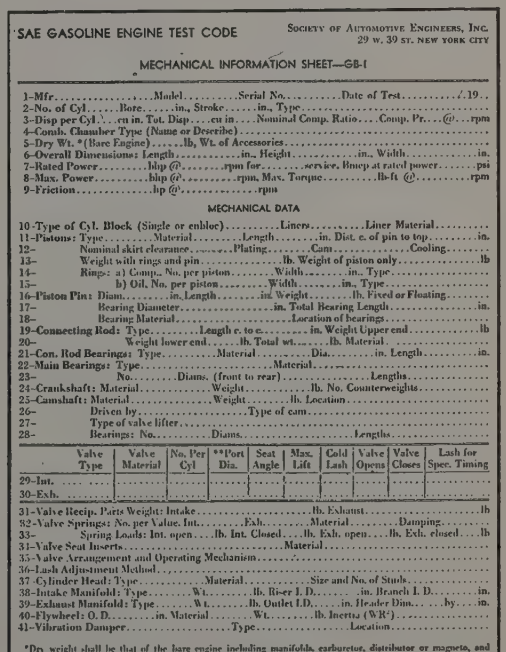
E. Power Test—For all power tests versus speed, a single series of stabilized runs at ascending speeds is sufficient. This series of runs should progress continuously from the lowest to the maximum rpm. Running straight through results in the least variations in temperature conditions, provided the test room at all times has adequate ventilation and temperature control. If the engine must be idled between runs to avoid excessively high temperatures, sufficient time must be allowed for the engine again to reach its stabilized condition before taking data. The brake load recorded must be substantially steady and constant throughout the run.

F. Engine RPM—Engine speed should be held as near constant as possible by means of applied dynamometer load, at wide-open throttle, or by throttle adjustment at part load.

G. Friction Horsepower—The friction horsepower test should follow immediately after the power test. The engine should be run out of fuel and motored with wide-open throttle at maximum rpm with oil and water temperatures held at the temperatures obtained on the corresponding power run. Sufficient time should be allowed to obtain a steady scale reading at each speed. Friction runs are made at the same speeds as used for the power runs in descending order.

H. Fuel Consumption—Fuel consumption is measured simultaneously with brake horsepower. The fuel consumption measurement must not be started until the engine is stabilized. A measuring interval of not less than 40 sec. is used when measuring speed and fuel consumption with the automatically synchronized counter-watch combination; for hand operation, not less than 60 sec. should be utilized. All specific fuel consumptions shall be based upon observed brake horsepower.

FIG. 1—FORM GA, RULES AND DIRECTIONS (FRONT OF FORM)



SAE GASOLINE ENGINE TEST CODE

Society of Automotive Engineers, Inc.
29 W. 39 St. New York City

MECHANICAL INFORMATION SHEET—GB-1

1–Mfr.....Model.....Serial No.....Date of Test.....19..
2–No. of Cyl.....Bore.....in., Stroke.....in., Type.....
3–Disp per Cyl.....cu in. Tot. Disp.....cu in.....Nominal Comp. Ratio.....Comp. Pr.....@.....rpm
4–Comb. Chamber Type (Name or Describe).....
5–Dry Wt.* (Bare Engine).....lb, Wt. of Accessories.....
6–Overall Dimensions: Length.....in., Height.....in., Width.....in.
7–Rated Power.....bhp @.....rpm for.....service, Bmep at rated power.....psi
8–Max. Power.....bhp @.....rpm, Max. Torque.....lb-ft @.....rpm
9–Friction.....hp @.....rpm

MECHANICAL DATA

10–Type of Cyl. Block (Single or enbloc).....Liners.....Liner Material.....
11–Pistons: Type.....Material.....Length.....in. Dist. c. of pin to top.....in.
12– Nominal skirt clearance.....Plating.....Cam.....Cooling.....
13– Weight with rings and pin.....lb. Weight of piston only.....lb
14– Rings: a) Comp.. No. per piston.....Width.....in.. Type.....
15– b) Oil. No. per piston.....Width.....in.. Type.....
16–Piston Pin: Diam.....in. Length.....in. Weight.....lb. Fixed or Floating.....
17– Bearing Diameter.....in. Total Bearing Length.....in.
18– Bearing Material.....Location of bearings.....
19–Connecting Rod: Type.....Length c. to c.....in. Weight Upper end.....lb
20– Weight lower end.....lb. Total wt.....lb. Material.....
21–Con. Rod Bearings: Type.....Material.....Dia.....in. Length.....in.
22–Main Bearings: Type.....Material.....
23– No.....Diams. (front to rear).....Lengths.....
24–Crankshaft: Material.....Weight.....lb. No. Counterweights.....
25–Camshaft: Material.....Weight.....lb. Location.....
26– Driven by.....Type of cam.....
27– Type of valve lifter.....
28– Bearings: No.....Diams.....Lengths.....

	Valve Type	Valve Material	No. Per Cyl	**Port Dia.	Seat Angle	Max. Lift	Cold Lash	Valve Opens	Valve Closes	Lash for Spec. Timing
29–Int.										
30–Exh.										

31–Valve Recip. Parts Weight: Intake.....lb. Exhaust.....lb
32–Valve Springs: No. per Value. Int.....Exh.....Material.....Damping.....
33– Spring Loads: Int. open.....lb. Int. Closed.....lb. Exh. open.....lb. Exh. closed.....lb
34–Valve Seat Inserts.....Material.....
35–Valve Arrangement and Operating Mechanism.....
36–Lash Adjustment Method.....
37–Cylinder Head: Type.....Material.....Size and No. of Studs.....
38–Intake Manifold: Type.....Wt.....lb. Ri-er I. D.....in. Branch I. D.....in.
39–Exhaust Manifold: Type.....Wt.....lb. Outlet I.D.....in. Header Dim.....by.....in.
40–Flywheel: O. D.....in. Material.....Wt.....lb. Inertia (WR²).....
41–Vibration Damper.....Type.....Location.....

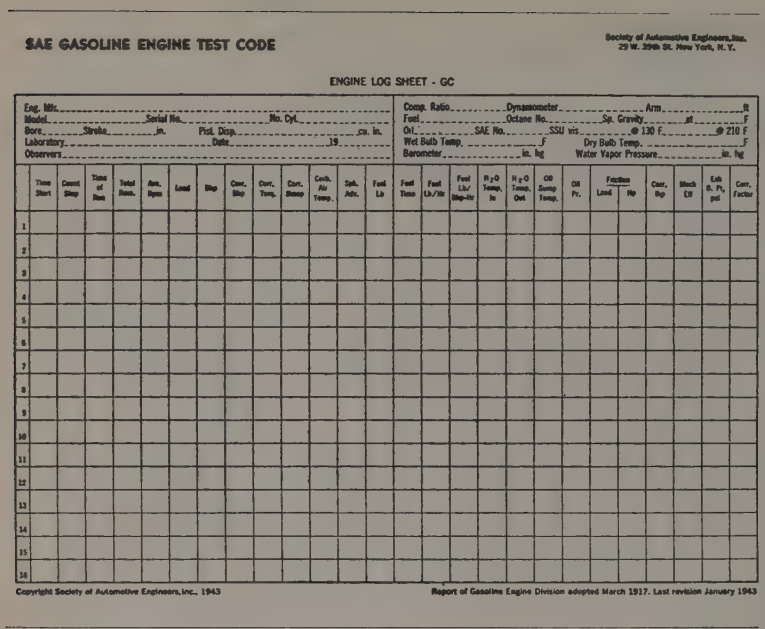
*Dry weight shall be that of the bare engine including manifolds, carburetor, distributor or magneto, and flywheel. The weight of other accessories shall be listed separately.

**The valve port diameter should show the small diameter of the seat rather than the actual port diameter, as the former gives the proper area for the control of the flow through the valve.

(Continued on Sheet GB-2)

FIG. 3—FORM GB, MECHANICAL INFORMATION SHEET

(*Continued on next page.*)



SAE GASOLINE ENGINE TEST CODE

Society of Automotive Engineers, Inc.
29 W. 39th St. New York, N. Y.

ENGINE LOG SHEET - GC

Eng. Mfr. _____ Model _____ Serial No. _____ No. Cyl. _____
Bore _____ Stroke _____ in. Pist. Disp. _____ cu. in.
Laboratory _____ Date _____ 19 _____
Observers _____

Comp. Ratio _____ Dynamometer _____ Arm _____ ft
Fuel _____ Octane No. _____ Sp. Gravity _____ at _____ F
Oil _____ SAE No. _____ SSU vis _____ @ 130 F. _____ @ 210 F
Wet Bulb Temp. _____ F Dry Bulb Temp. _____ F
Barometer _____ in. hg Water Vapor Pressure _____ in. hg

	Time Start	Count Step	Time of Run	Total Revs.	Ave. Rpm	Load	Bhp	Corr. Bhp	Corr. Torq.	Corr. Steep	Carb. Air Temp.	Spk. Adv.	Fuel Lb	Fuel Time	Fuel Lb/Hr	Fuel Lb/ Bhp-Hr	H_2O Temp. In	H_2O Temp. Out	Oil Sump Temp.	Oil Pr.	Friction Load	Friction Hp	Corr. Bsp	Mech Eff	Exh B. Pr. psi	Corr. Factor
1																										
2																										
3																										
4																										
5																										
6																										
7																										
8																										
9																										
10																										
11																										
12																										
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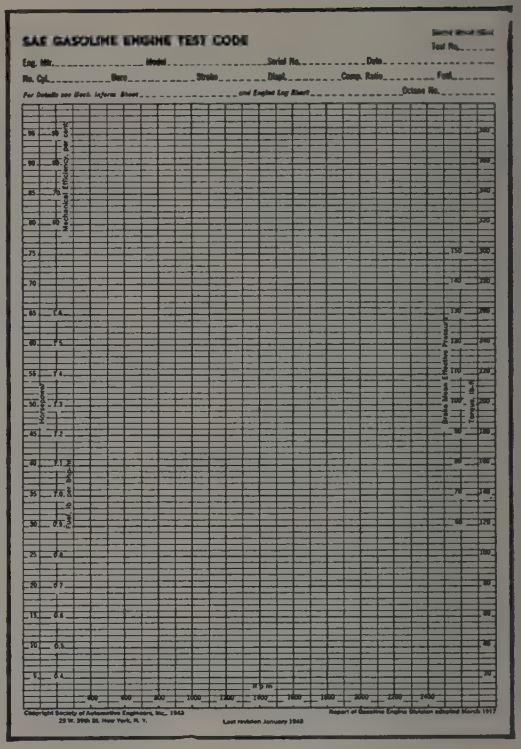
Report of Gasoline Engine Division adopted March 1917. Last revision January 1943

FIG. 4—FORM GC, ENGINE LOG SHEET



SAE GASOLINE ENGINE TEST CODE

Eng. Mfr. _____ Model _____ Serial No. _____ Date _____
No. Cyl. _____ Bore _____ Stroke _____ Displ. _____ Comp. Ratio _____ Fuel _____
For Details see Work Inform Sheet _____ and Engine Log Sheet _____ Octane No. _____

Mechanical Efficiency, per cent
Fuel per Bhp-hr
Brake Mean Effective Pressure
Torque, lb-ft
B P, hp

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Last revision January 1943

Report of Gasoline Engine Division adopted March 1917

FIG. 5—FORM GD1, CURVE SHEET

Insert Valve Seats

SAE Recommended Practice

Report of Gasoline Engine Division approved January 1937.

[*The principal dimensions given in this Standard relate to the bore in the cylinder head rather than to the inserts themselves, because of the difference in required fits and physical characteristics of various insert materials. Accordingly, engine designs can be uniformly dimensioned to provide for interchangeability of various inserts, the insert manufacturer selecting the proper dimensions for the particular material he uses. The regular series is intended primarily for use in passenger-car engines and the heavy-duty series for engines in trucks, buses, tractors, and for other heavy-duty services.*]

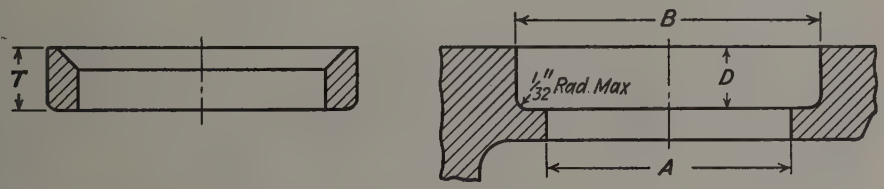


TABLE 1—*Dimensions for Bores*[a] *in Cylinder Head and Insert Valve Seats*

Nominal valve throat diameter, *A*, in.	Regular series			Heavy-duty series		
	Bore, *B*, in., ±0.0005	Bore depth, *D*, in., +0.005 −0.000	Insert thickness, *T*, in.	Bore, *B*, in., ±0.0005	Bore depth, *D*, in., +0.005 −0.000	Insert thickness, *T*, in.
7/8	1.1250 (1 1/8)	0.224	7/32	1.1250 (1 1/8)	0.260	1/4
15/16	1.1875 (1 3/16)	0.224	7/32	1.1875 (1 3/16)	0.260	1/4
1	1.2500 (1 1/4)	0.224	7/32	1.2500 (1 1/4)	0.260	1/4
1 1/16	1.3125 (1 5/16)	0.224	7/32	1.3750 (1 3/8)	0.323	5/16
1 1/8	1.3750 (1 3/8)	0.224	7/32	1.4375 (1 7/16)	0.323	5/16
1 3/16	1.4375 (1 7/16)	0.224	7/32	1.5000 (1 1/2)	0.323	5/16
1 1/4	1.5000 (1 1/2)	0.255	1/4	1.5625 (1 9/16)	0.323	5/16
1 5/16	1.5625 (1 9/16)	0.255	1/4	1.6875 (1 11/16)	0.385	3/8
1 3/8	1.6250 (1 5/8)	0.255	1/4	1.7500 (1 3/4)	0.385	3/8
1 7/16	1.6875 (1 11/16)	0.255	1/4	1.8125 (1 13/16)	0.385	3/8
1 1/2	1.8125 (1 13/16)	0.318	5/16	1.8750 (1 7/8)	0.385	3/8
1 9/16	1.8750 (1 7/8)	0.318	5/16	2.0000	0.448	7/16
1 5/8	1.9375 (1 15/16)	0.318	5/16	2.0625 (2 1/16)	0.448	7/16
1 11/16	2.0000	0.318	5/16	2.1250 (2 1/8)	0.448	7/16
1 3/4	2.1250 (2 1/8)	0.380	3/8	2.1875 (2 3/16)	0.448	7/16
1 13/16	2.1875 (2 3/16)	0.380	3/8	2.2500 (2 1/4)	0.448	7/16
1 7/8	2.2500 (2 1/4)	0.380	3/8	2.3125 (2 5/16)	0.448	7/16
1 15/16	2.3125 (2 5/16)	0.380	3/8	2.4375 (2 7/16)	0.510	1/2
2	2.3750 (2 3/8)	0.380	3/8	2.5000 (2 1/2)	0.510	1/2
2 1/16	—	—	—	2.5625 (2 9/16)	0.510	1/2
2 1/8	—	—	—	2.6250 (2 5/8)	0.510	1/2
2 3/16	—	—	—	2.6875 (2 11/16)	0.510	1/2
2 1/4	—	—	—	2.7500 (2 3/4)	0.510	1/2
2 5/16	—	—	—	2.8750 (2 7/8)	0.573	9/16
2 3/8	—	—	—	2.9375 (2 15/16)	0.573	9/16
2 7/16	—	—	—	3.0000	0.573	9/16
2 1/2	—	—	—	3.0625 (3 1/16)	0.573	9/16
2 5/8	—	—	—	3.1875 (3 3/16)	0.573	9/16
2 3/4	—	—	—	3.3125 (3 5/16)	0.573	9/16

[a] The sides and bottom of the bore shall be square with a smooth, even finish and with no tool marks so as to give a good, even fit for the insert.

Piston Rings and Grooves

SAE Standard

Report of Miscellaneous Division approved August 1916 and last revised by Gasoline Engine Division January 1942.

[*This Standard applies primarily to the types of internal-combustion engines commonly used in automobiles, motorboats, and similar products. For pistons used in aircraft engines and engines not of the conventional automobile type, it may be necessary to deviate from the rings and grooves recommended in order to secure most satisfactory performance, but such modifications should not be made by changing the piston-ring width or radial wall.*]

TABLE 1—*Piston-Ring and Groove Widths*[a]

NOMINAL RING WIDTH	ALL RING WIDTHS, IN.			RING-GROOVE WIDTHS, IN.							
				Top compression-ring grooves only				Additional compression- and oil-ring grooves			
	All diam	Under 6 in. diam	6 to 8 in. diam	1 to 4 1/16 in. diam, inclusive		4 3/4 to 8 in. diam, inclusive		1 to 4 1/16 in. diam, inclusive		4 3/4 to 8 in. diam, inclusive	
	Max	Min	Min	Max	Min	Max	Min	Max	Min	Max	Min
1/16	0.0625	0.0620	0.0615	0.0650	0.0640	0.0655	0.0645	0.0645	0.0635	0.0650	0.0640
5/64	0.0780	0.0775	0.0770	0.0805	0.0795	0.0810	0.0800	0.0800	0.0790	0.0805	0.0795
3/32	0.0935	0.0930	0.0925	0.0960	0.0950	0.0965	0.0955	0.0955	0.0945	0.0960	0.0950
1/8	0.1240	0.1235	0.1230	0.1265	0.1255	0.1270	0.1260	0.1260	0.1250	0.1265	0.1255
5/32	0.1550	0.1545	0.1540	0.1575	0.1565	0.1580	0.1570	0.1570	0.1560	0.1575	0.1565
3/16	0.1865	0.1860	0.1855	0.1890	0.1880	0.1895	0.1885	0.1885	0.1875	0.1890	0.1880
1/4	0.2490	0.2485	0.2480	0.2515	0.2505	0.2520	0.2510	0.2510	0.2500	0.2515	0.2505

[a] The piston-ring grooves in Table 1 provide for a minimum side clearance of 0.001 in. for cylinders under 4 3/4 in. diameter and 0.0015 in. for cylinders 4 3/4 to 8 in. diameter, inclusive. The greater clearance for the top compression ring only is recommended in order to give improved ring performance. Deviation from the clearance standards may be necessary depending on the type of ring used.

TABLE 2—*Ring Widths for Cylinder Diameters*

CYLINDER DIAMETER, IN., INCLUSIVE	RING WIDTH, IN.								
	Compression rings[a]					Oil rings			
1 to 2 15/16	3/32	—	—	—	—	1/8	5/32	3/16	—
3 to 3 15/16	3/32	1/8	—	—	—	—	5/32	3/16	1/4
4 to 5 15/16	3/32	1/8	5/32	—	—	—	—	3/16	1/4
6 to 8	—	1/8	5/32	3/16	1/4	—	—	—	1/4

[a] Narrower compression-ring widths specified above are recommended unless application dictates otherwise. Use oil-ring widths as great as space will permit.

Formulas for Ring Grooves—The groove-bottom diameters were calculated from the following formulas:

Compression-Ring Grooves

For aluminum pistons,

$$A = D - (2T + 0.006D + 0.020)$$

For cast-iron pistons,

$$A = D - (2T + 0.004D + 0.020)$$

Oil-Ring Grooves

For aluminum pistons,

$$A = D - (2T + 0.006D + 0.060)$$

For cast-iron pistons,

$$A = D - (2T + 0.004D + 0.060)$$

For All Rings

$$B = A - 0.010$$

where: A = high limit for groove-bottom diameter
B = low limit for groove-bottom diameter
D = nominal cylinder diameter
T = maximum ring wall

Cylinder Diameter—It is recommended that the cylinder-diameter tolerance be specified as plus above the nominal diameter.

Eccentricity Tolerance—The manufacturing-eccentricity tolerance on the radial wall of all concentric rings and on rings up to 5 in. in diameter with rough-cast inside surface should be held to 0.010 in.; and on rings 5 to 8 in. in diameter, inclusive, with rough-case inside surface, to not more than 0.025 in.

The dimensions recommended are for automotive-engine conditions, and only maximum ring walls are specified in order to control the ring-groove-bottom diameters.

(*Continued on next page.*)

TABLE 3—*Piston-Ring Radial Wall and Groove Diameters*

CYLINDER DIAMETER, IN.	MAXIMUM RING RADIAL WALL, IN.	MAXIMUM RING-GROOVE-BOTTOM DIAM, IN.				CYLINDER DIAMETER, IN.	MAXIMUM RING RADIAL WALL, IN.	MAXIMUM RING-GROOVE-BOTTOM DIAM, IN.			
		Cast-iron pistons		Aluminum pistons				Cast-iron pistons		Aluminum pistons	
		Compression rings	Oil rings	Compression rings	Oil rings			Compression rings	Oil rings	Compression rings	Oil rings
1	0.050	0.876	0.836	0.874	0.834	4½	0.183	4.096	4.056	4.087	4.047
1 1/16	0.050	0.938	0.898	0.936	0.896	4 9/16	0.184	4.156	4.116	4.147	4.107
1⅛	0.055	0.990	0.950	0.988	0.948	4⅝	0.186	4.214	4.174	4.205	4.165
1 3/16	0.055	1.052	1.012	1.050	1.010	4 11/16	0.187	4.274	4.234	4.265	4.225
1¼	0.060	1.105	1.065	1.102	1.062	4¾	0.189	4.333	4.293	4.323	4.283
1 5/16	0.060	1.167	1.127	1.164	1.124	4 13/16	0.190	4.393	4.353	4.383	4.343
1⅜	0.065	1.219	1.179	1.217	1.177	4⅞	0.192	4.451	4.411	4.441	4.401
1 7/16	0.065	1.281	1.241	1.278	1.238	4 15/16	0.193	4.511	4.471	4.501	4.461
1½	0.070	1.334	1.294	1.331	1.291	5	0.195	4.570	4.530	4.560	4.520
1 9/16	0.070	1.396	1.356	1.393	1.353	5 1/16	0.196	4.630	4.590	4.620	4.580
1⅝	0.075	1.448	1.408	1.445	1.405	5⅛	0.197	4.690	4.650	4.680	4.640
1 11/16	0.075	1.510	1.470	1.507	1.467	5 3/16	0.199	4.748	4.708	4.738	4.698
1¾	0.080	1.563	1.523	1.559	1.519	5¼	0.200	4.809	4.769	4.798	4.758
1 13/16	0.080	1.625	1.585	1.621	1.581	5 5/16	0.200	4.871	4.831	4.860	4.820
1⅞	0.085	1.677	1.637	1.674	1.634	5⅜	0.205	4.923	4.883	4.912	4.872
1 15/16	0.085	1.739	1.699	1.735	1.695	5 7/16	0.205	4.985	4.945	4.974	4.934
2	0.090	1.792	1.752	1.788	1.748	5½	0.210	5.038	4.998	5.027	4.987
2 1/16	0.090	1.854	1.814	1.850	1.810	5 9/16	0.210	5.100	5.060	5.089	5.049
2⅛	0.100	1.896	1.856	1.892	1.852	5⅝	0.215	5.152	5.112	5.141	5.101
2 3/16	0.100	1.958	1.918	1.954	1.914	5 11/16	0.215	5.214	5.174	5.203	5.163
2¼	0.105	2.011	1.971	2.006	1.966	5¾	0.220	5.267	5.227	5.255	5.215
2 5/16	0.105	2.073	2.033	2.068	2.028	5 13/16	0.220	5.329	5.289	5.317	5.277
2⅜	0.110	2.125	2.085	2.120	2.080	5⅞	0.225	5.381	5.341	5.369	5.329
2 7/16	0.114	2.179	2.139	2.174	2.134	5 15/16	0.225	5.443	5.403	5.431	5.391
2½	0.117	2.236	2.196	2.231	2.191	6	0.230	5.496	5.456	5.484	5.444
2 9/16	0.120	2.292	2.252	2.287	2.247	6 1/16	0.230	5.558	5.518	5.546	5.506
2⅝	0.122	2.350	2.310	2.345	2.305	6⅛	0.235	5.610	5.570	5.598	5.558
2 11/16	0.125	2.406	2.366	2.401	2.361	6 3/16	0.235	5.672	5.632	5.660	5.620
2¾	0.128	2.463	2.423	2.457	2.417	6¼	0.240	5.725	5.685	5.712	5.672
2 13/16	0.131	2.519	2.479	2.513	2.473	6 5/16	0.240	5.787	5.747	5.774	5.734
2⅞	0.133	2.577	2.537	2.571	2.531	6⅜	0.245	5.839	5.799	5.826	5.786
2 15/16	0.136	2.633	2.593	2.627	2.587	6 7/16	0.245	5.901	5.861	5.888	5.848
3	0.139	2.690	2.650	2.684	2.644	6½	0.250	5.954	5.914	5.941	5.901
3 1/16	0.142	2.746	2.706	2.740	2.700	6 9/16	0.250	6.016	5.976	6.003	5.963
3⅛	0.144	2.804	2.764	2.798	2.758	6⅝	0.255	6.068	6.028	6.055	6.015
3 3/16	0.147	2.860	2.820	2.854	2.814	6 11/16	0.255	6.130	6.090	6.117	6.077
3¼	0.150	2.917	2.877	2.910	2.870	6¾	0.260	6.183	6.143	6.169	6.129
3 5/16	0.152	2.975	2.935	2.968	2.928	6 13/16	0.260	6.245	6.205	6.231	6.191
3⅜	0.153	3.035	2.995	3.028	2.988	6⅞	0.265	6.297	6.257	6.283	6.243
3 7/16	0.155	3.093	3.053	3.086	3.046	6 15/16	0.265	6.359	6.319	6.345	6.305
3½	0.157	3.152	3.112	3.145	3.105	7	0.270	6.412	6.372	6.398	6.358
3 9/16	0.158	3.212	3.172	3.205	3.165	7 1/16	0.270	6.474	6.434	6.460	6.420
3⅝	0.160	3.270	3.230	3.263	3.223	7⅛	0.270	6.536	6.496	6.522	6.482
3 11/16	0.162	3.328	3.288	3.321	3.281	7 3/16	0.270	6.598	6.558	6.584	6.544
3¾	0.163	3.389	3.349	3.381	3.341	7¼	0.275	6.651	6.611	6.636	6.596
3 13/16	0.165	3.447	3.407	3.439	3.399	7 5/16	0.275	6.713	6.673	6.698	6.658
3⅞	0.167	3.504	3.464	3.497	3.457	7⅜	0.280	6.765	6.725	6.750	6.710
3 15/16	0.169	3.563	3.523	3.555	3.515	7 7/16	0.280	6.827	6.787	6.812	6.772
4	0.170	3.624	3.584	3.616	3.576	7½	0.285	6.880	6.840	6.865	6.825
4 1/16	0.172	3.682	3.642	3.674	3.634	7 9/16	0.285	6.942	6.902	6.927	6.887
4⅛	0.174	3.740	3.700	3.732	3.692	7⅝	0.290	6.994	6.954	6.979	6.939
4 3/16	0.175	3.800	3.760	3.792	3.752	7 11/16	0.290	7.056	7.016	7.041	7.001
4¼	0.177	3.859	3.819	3.850	3.810	7¾	0.295	7.109	7.069	7.093	7.053
4 5/16	0.179	3.917	3.877	3.908	3.868	7 13/16	0.295	7.171	7.131	7.155	7.115
4⅜	0.181	3.975	3.935	3.966	3.926	7⅞	0.300	7.223	7.183	7.207	7.167
4 7/16	0.182	4.035	3.995	4.026	3.986	7 15/16	0.300	7.285	7.245	7.269	7.229
						8	0.305	7.338	7.298	7.322	7.282

(*Continued on next page.*)

TABLE 4—*Piston-Ring Radial Wall and Groove Diameters for Thick-Wall Compression Rings*[a]

CYLINDER DIAMETER, IN.	MAXIMUM RING RADIAL WALL, IN.	MAXIMUM RING-GROOVE-BOTTOM DIAM, IN. (COMPRESSION RINGS ONLY)		CYLINDER DIAMETER, IN.	MAXIMUM RING RADIAL WALL, IN.	MAXIMUM RING-GROOVE-BOTTOM DIAM, IN. (COMPRESSION RINGS ONLY)	
		Cast-iron pistons	Aluminum pistons			Cast-iron pistons	Aluminum pistons
2	0.100	1.772	1.768	3 1/2	0.175	3.116	3.109
2 1/16	0.103	1.828	1.824	3 9/16	0.178	3.172	3.165
2 1/8	0.106	1.884	1.880	3 5/8	0.181	3.228	3.221
2 3/16	0.109	1.940	1.936	3 11/16	0.184	3.284	3.277
2 1/4	0.112	1.997	1.992	3 3/4	0.187	3.341	3.333
2 5/16	0.116	2.051	2.046	3 13/16	0.191	3.395	3.387
2 3/8	0.119	2.107	2.103	3 7/8	0.194	3.451	3.444
2 7/16	0.122	2.163	2.158	3 15/16	0.197	3.507	3.499
2 1/2	0.125	2.220	2.215	4	0.200	3.564	3.556
2 9/16	0.128	2.276	2.271	4 1/16	0.203	3.620	3.612
2 5/8	0.131	2.332	2.327	4 1/8	0.206	3.676	3.668
2 11/16	0.134	2.388	2.383	4 3/16	0.209	3.732	3.724
2 3/4	0.137	2.445	2.439	4 1/4	0.212	3.789	3.780
2 13/16	0.141	2.499	2.493	4 5/16	0.216	3.843	3.834
2 7/8	0.144	2.555	2.550	4 3/8	0.219	3.899	3.891
2 15/16	0.147	2.611	2.605	4 7/16	0.222	3.955	3.946
3	0.150	2.668	2.662	4 1/2	0.225	4.012	4.003
3 1/16	0.153	2.724	2.718	4 9/16	0.228	4.068	4.059
3 1/8	0.156	2.780	2.774	4 5/8	0.231	4.124	4.115
3 3/16	0.159	2.836	2.830	4 11/16	0.234	4.180	4.171
3 1/4	0.162	2.893	2.886	4 3/4	0.237	4.237	4.227
3 5/16	0.166	2.947	2.940	4 13/16	0.241	4.291	4.281
3 3/8	0.169	3.003	2.997	4 7/8	0.244	4.347	4.338
3 7/16	0.172	3.059	3.052	4 15/16	0.247	4.403	4.393
				5	0.250	4.460	4.450

[a] Thick-wall specification is applicable to compression-ring types only. Thick-wall rings are for use in high-output applications in top compression-ring grooves and may be used in lower-compression grooves. Thick-wall rings are recommended from 2 to 5 in. in diameter and 3/32 in. in width; 1/8-in. wide rings may be used from 4 to 5 in. in diameter, inclusive.

A cross index of SAE designations for materials and parts appears after the last standard in this book.

Piston-Ring End Clearance and Drain Holes

SAE Recommended Practice

Report of Miscellaneous Division approved August 1916 and last revised by Gasoline Engine Division January 1942.

Piston-ring end clearance must be determined from the minimum cylinder diameter. It is recommended that end clearance for rings be as shown in Table 1.

TABLE 1—*Ring End Clearance*

CYLINDER DIAMETER, IN., INCLUSIVE	END CLEARANCE, IN.
1 to 1 15/16	0.005 to 0.015
2 to 3 15/16	0.007 to 0.017
4 to 5 15/16	0.010 to 0.020
6 to 8	0.015 to 0.025

TABLE 2—*Number of Oil-Ring Groove Drain Holes*

CYLINDER DIAMETER, IN., INCLUSIVE	NUMBER OF HOLES
2 to 2 1/2	8
2 9/16 to 2 15/16	10
3 to 3 7/16	12
3 1/2 to 3 15/16	14
4 to 4 1/2	12
4 9/16 to 5 7/16	14
5 1/2 to 5 15/16	16
6 to 6 5/8	14
6 11/16 to 7 15/16	16
8	17

TABLE 3—*Size of Oil-Ring Groove Drain Holes*

NOMINAL RING WIDTH, IN.	DRILL HOLE DIAMETER, IN.
1/8	3/32
5/32	1/8
3/16	5/32
1/4	7/32

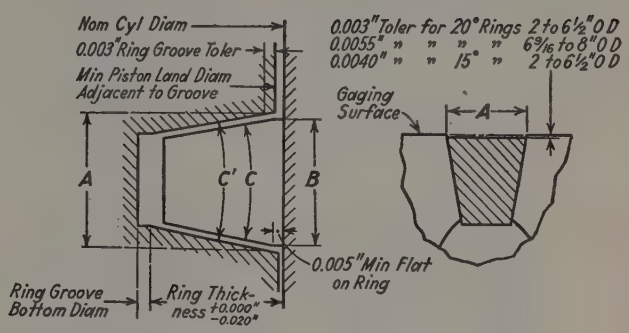

Nom Cyl Diam
0.003" Ring Groove Toler
Min Piston Land Diam Adjacent to Groove
0.003" Toler for 20° Rings 2 to 6½" O D
0.0055" " " " " 6 9/16 to 8" O D
0.0040" " " 15° " 2 to 6½" O D
Gaging Surface
A
A
C' C
B
0.005" Min Flat on Ring
Ring Groove Bottom Diam
Ring Thickness +0.000" -0.020"

FIG. 1—"K"-TYPE RING AND GROOVE

TABLE 4—*"K"-Type Ring and Groove Dimensions*[a]

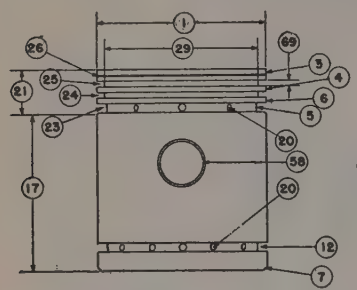
NOMINAL RING SIZE	*A*	*B*, IN., FOR CYLINDER DIAMETER		*C*, RING DEG, +15 MIN	*C'*, GROOVE DEG, −15 MIN
		2 to 6½	6 9/16 to 8		
3/32	0.0935	0.0890	—	15	15
1/8	0.1240	0.1195	0.1185	15 or 20	15 or 20
5/32	0.1550	0.1505	0.1495	20	20
3/16	0.1865	0.1820	0.1810	20	20
1/4	0.2490	0.2445	0.2435	20	20
5/16	0.3115	0.3070	0.3060	20	20
3/8	0.3740	0.3696	0.3685	20	20

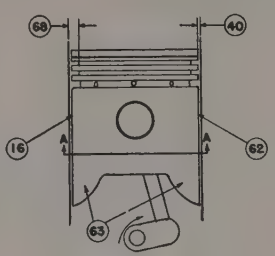
[a] The "K"-type of ring is commonly used in high-output internal-combustion engines where ring sticking is a problem. These standards are recommended where this ring is considered but should not be construed as a recommendation for this type of ring if conventional rings are satisfactory.

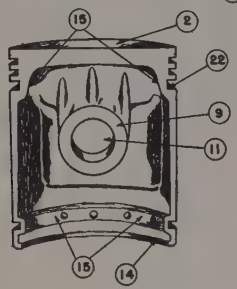
Piston and Ring Nomenclature

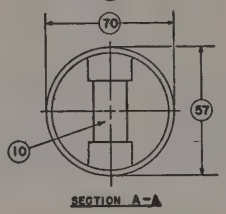
SAE Recommended Practice

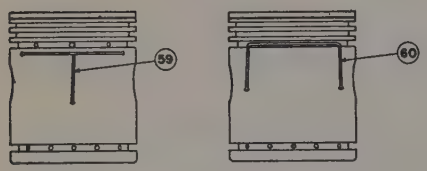
Report of Gasoline Engine Division approved January 1944.

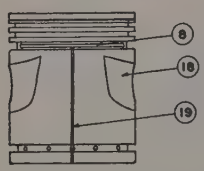












Nomenclature

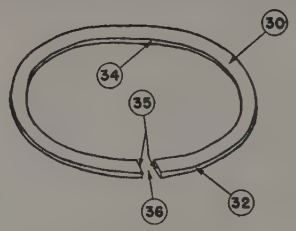
2—Head
3—Top Land
4—2nd Land
5—Ring-Groove Bottom
6—3rd Land
7—Chamfer
8—Horizontal Slot
9—Pin Boss
10—Piston Pin
11—Pin Hole
12—Skirt Ring Groove
14—Bottom Rib
15—Ring-Groove Pad
16—Major Thrust Face
17—Skirt
18—Skirt Relief
19—Vertical Slot
20—Oil Drain Holes
21—Ring Belt
22—Ring-Groove Side
23—Oil-Ring Groove
24—2nd-Ring Groove
25—Top-Ring Groove
26—Heat Dam
58—Pin Bushing
59—T-Slot
60—U-Slot
62—Minor Thrust Face
63—Slippers

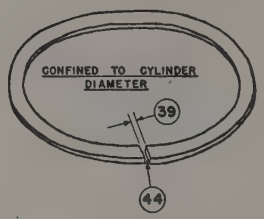
Dimensional Terms

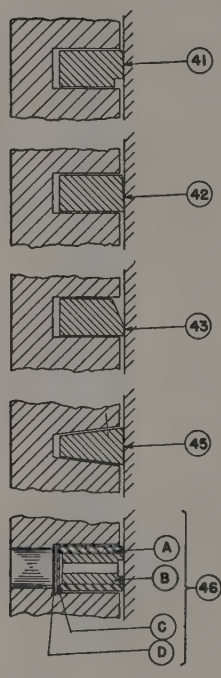
1—Land Diameter
29—Groove-Bottom Diameter
40—Land Clearance
57—Minor Diameter
68—Groove Depth
69—Groove Width
70—Major Diameter

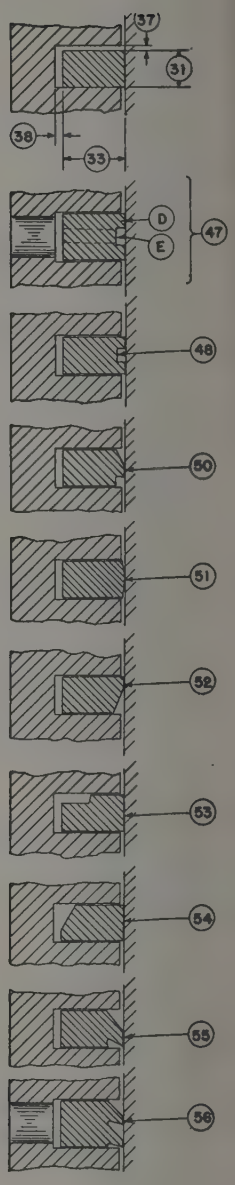
Dimensional Terms

31—Width
33—Wall
37—Side Clearance
38—Back Clearance
39—End Clearance









Nomenclature

30—Side
32—Face
34—Back
35—Ends
36—Free Gap
41—Scraper
42—Taper Face
43—Bevel
44—Compressed Gap
45—Keystone
46—Multipiece
A—Rail
B—Ventilated Spacer
C—Expander
D—Shim
47—Ventilated Oil (drilled or slotted)
D—Flange
E—Channel
48—Grooved
50—Bevel Scraper
51—Double Taper
52—Inverted Bevel
53—Counterbored
54—Inside Bevel
55—Single Hook
56—Double Hook

Engine Mountings

SAE Standard

Report of Engine Division approved April 1919 and last revised January 1942.

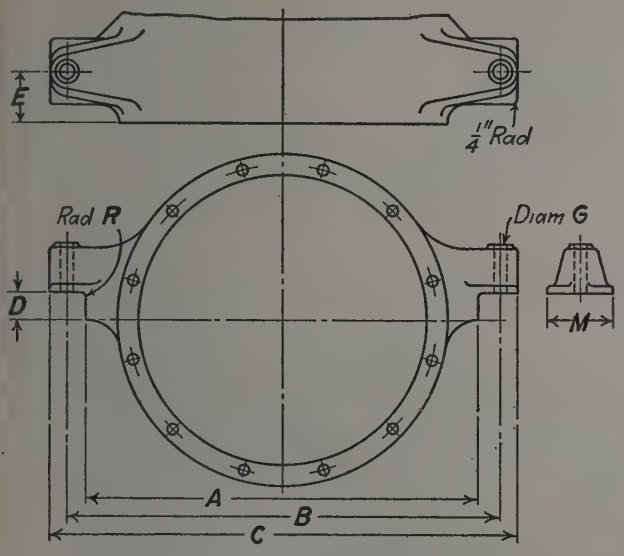


FIG. 1—ENGINE ARM

TABLE 1—*Engine-Arm Dimensions*

SIZE NO.	*A*	*B*	*C*	*D*	*E*	*G*	*R*, MAX	*M*
1	23½	26¾	28¾	2	3	25/32	7/16	4
3	22½	24½	25¾	2½	3	21/32	¼	3½
4	22½	24½	25¾	2½	3	21/32	¼	2¾
5	22½	24½	25¾	2½	3	21/32	¼	2¾
2T	20	21¾	23½	3	3	21/32	¼	4

TABLE 2—*Engine-Trunnion Dimensions*

TYPE	DIAMETER, IN.	LENGTH, IN.
Starting-crank bracket.....	2½	1¼
	3	1¼
Gear cover.....	3¾	1½
	5	1½

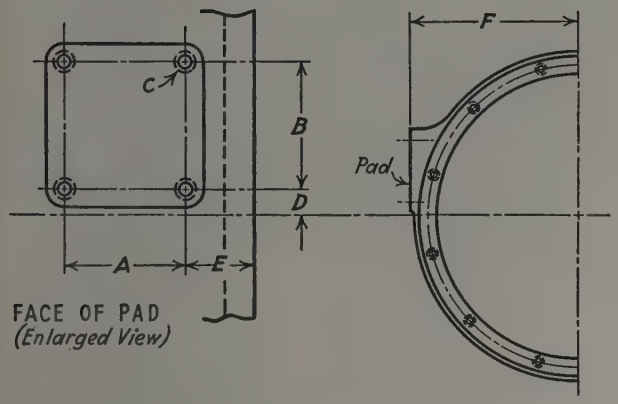


FIG. 2—FLAT-PAD MOUNTING

TABLE 3—*Flat-Pad Mounting Dimensions*

SAE Housing Number	*A*	*B*	*C*	*D*	*E*	*F*	APPROXIMATE ENGINE DISPLACEMENT, CU IN.
6, 4 and 5, 3	2	2⅝	½–13	⅝	1 1/16	7⅜, 8⅜, 10¼	Up to 450
2, 1	2½	3½	½–13	⅝	1¾	10¼, 11	450 to 800
1, 0	3½	4½	⅝–11	¾	1	11, 14½	800 and over

Engine Flywheel Housings

SAE Standard

Report of Flywheel Housing Division approved March 1916 and last revised by Gasoline Engine Division January 1941.

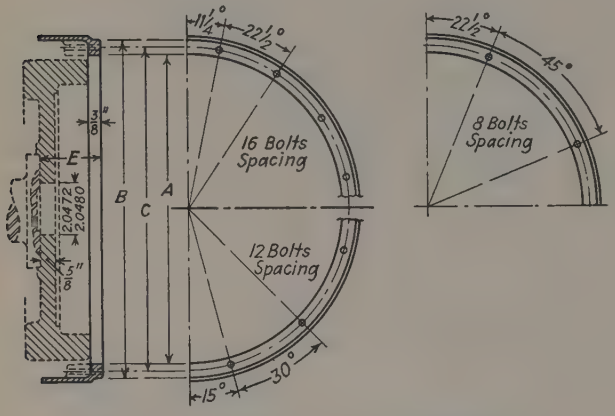


FIG. 1—FLYWHEEL-HOUSING DIMENSIONS

Table 1 and Fig. 1 give dimensions for flywheel housings. Fig. 1 also shows spacings for eight, twelve, and sixteen bolts.

Clutch Housings—The capscrew holes in the clutch-housing flanges shall be $\frac{3}{64}$ in. larger than the nominal diameter of the flywheel-housing capscrews.

The diameter of the pilot on the flange of the clutch housing shall be the same as the nominal diameter of the bore in the flywheel housing; the tolerances shall be plus 0.000 and minus 0.005 in.; and the maximum eccentricity shall be 0.0025 in. (indicated runout, 0.005 in.).

The maximum variation of the face of the clutch-housing flange from its true position, when rotated about its axis, shall be 0.0025 in. (indicated runout, 0.005 in.).

TABLE 1—*Flywheel-Housing Dimensions*

SAE Size No.	*A*	*B*	*C*	*D*	DEPTH, *E*	CAPSCREW[a] No.	CAPSCREW[a] Size
00	31	34¾	33½	35	3 15/16	16	½–
0	25½	28	26¾	28½	3 15/16	16	½–
1	20⅛	21¾	20⅞	—	3 15/16	12	⅜–
2	17⅝	19¼	18⅜	—	3 15/16	12	⅜–
3	16⅛	17¾	16⅞	—	3 15/16	12	⅜–
4	14¼	15⅞	15	—	3 15/16	12	⅜–
5	12⅜	14	13⅛	—	2 13/16	8	⅜–
6	10½	12⅛	11¼	—	2 13/16	8	⅜–

[a] Capscrews shall be threaded in accordance with the Class 2 tolerances of the S Standard for Screw Threads and shall be equally spaced on each side of the vert centerline.

The tolerance for the flywheel-housing bore shall be plus 0.005 in. and minus 0. and the maximum eccentricity 0.005 in. (indicator reading, 0.010 in.), except for No. 0 and 00 sizes, which shall be plus 0.010 in. and minus 0.000.

The maximum deviation of the face of the flywheel-housing flange from its t position, when the housing is rotated on its axis, shall be 0.003 in. (indicated run 0.006 in.).

Disc-Clutch Flywheels—Fixed dimensions do not apply flywheels for the No. 5 and No. 6 housings.

The maximum variation of the counterbored surface of t flywheel from its true position, when the flywheel is rotated its axis, shall be 0.0025 in. when measured at a radius of 5 in. (indicated runout, 0.005 in.).

The maximum eccentricity for the 11½-in. counterbore in t flywheel shall be 0.0025 in. (indicated runout, 0.005 in.).

The maximum eccentricity for the bore in the flywheel the pilot bearing shall be 0.0025 in. (indicated runout, 0.005 in

The maximum distance from the flywheel face to the ends the crankshaft flywheel bolts shall be $1\frac{1}{16}$ in.

Airflow- or Vacuum-Governor Flanges

SAE Standard

Report of Engine Technical Committee approved January 1951.

Table 1 gives dimensions of single-orifice, 2-bolt governor flanges. The general outline of this type flange (Fig. 1) is not intended to confine dimensionally future designs.

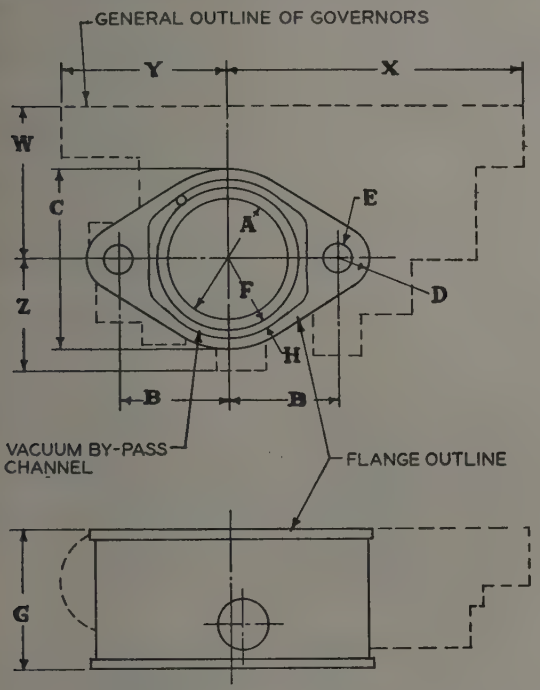


FIG. 1—SINGLE-ORIFICE, 2-BOLT GOVERNOR FLANGE

TABLE 1—*Dimensions of Single-Orifice, 2-Bolt Governor Flanges*

	SAE FLANGE SIZE, IN.				
	1	1¼	1½	1¾	2
Bore size, *A*	1.000[a]	1.187[b]	1.500[a]	1.937[c]	2.187
	1.094[b]	1.209[d]	1.512[d]		
	1.187[c]	1.250[a]	1.562[b]		
	1.209[d]	1.437[b]	1.687[c]		
	1.250[a]	1.500[a]	1.694[d]		
	1.312[d]	1.503[d]			
B	1.187	1.343	1.468	1.656	1.781
C	1.875[c]	2.187[c]	2.500	2.812	3.125
	2.187[d]	2.312[a]			
D	0.343[c]	0.406	0.406	0.468	0.468
	0.406[d]				
E	0.343	0.406	0.406	0.468	0.468
F	0.718	0.875	1.000	1.125	1.281
G	1.500[a]	1.437[b]	1.437[b]	2.000[b]	2.250
	1.687[d]	1.687[c]	1.718[d]	2.125[a]	
	1.875[b]		1.750[a]		
H	0.093	0.093	0.125	0.125	0.125
W (approx)	2.06	2.12	2.22	2.72	2.80
X (approx)	3.78	3.78	3.78	3.12	3.12
Y (approx)	2.25	2.25	2.25	2.25	2.25
Z (approx)	1.33	1.33	1.45	1.69	1.81

[a] These dimensions pertain to the same flange.
[b] These dimensions pertain to the same flange.
[c] These dimensions pertain to the same flange.
[d] These dimensions pertain to the same flange.

Table 2 gives dimensions of double-orifice, 3-bolt governor flanges. Orifices may be round or rectangular. The general outline (Fig. 2) is not intended to confine dimensionally future designs.

Table 3 gives dimensions of double-orifice, 4-bolt governor

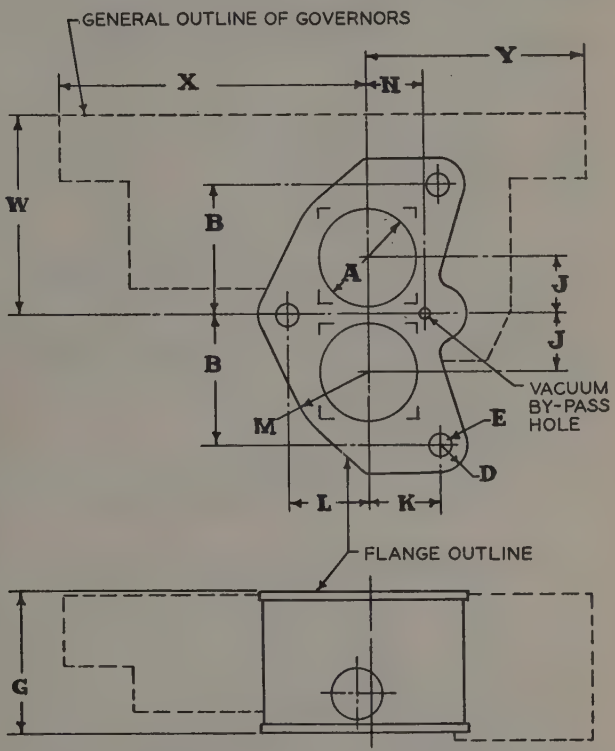


FIG. 2—DOUBLE-ORIFICE, 3-BOLT GOVERNOR FLANGE

TABLE 2—*Dimensions of Double-Orifice, 3-Bolt Governor Flanges*

	SAE FLANGE SIZE, IN.	
	¾	1
Bore Size, *A*	0.937[a]	1.093 x 1.156[c]
	1.028[b]	1.094[a]
		1.209[b]
B	1.562	1.562
D	0.343	0.343
E	0.343	0.343
G	1.125[a]	1.125[a]
	1.687[b]	1.625[c]
		1.687[b]
J	0.672	0.672
K	0.875	0.875
L	1.000	1.000
M	1.000	1.000
N	0.562	0.562
W (approx)	2.47	2.47
X (approx)	3.78	3.78
Y (approx)	2.13	2.13

[a] These dimensions pertain to the same flange.
[b] These dimensions pertain to the same flange.
[c] These dimensions pertain to the same flange.

flanges. Orifices may be round or rectangular. The general outline of this type flange (Fig. 3) is not intended to confine dimensionally future designs.

All governors listed in Tables 1, 2, and 3 have been tested and are in production.

Typical airflow-type governor loading and unloading curves are shown in Fig. 4.

The terms defined in this SAE Standard apply to airflow- or vacuum-type governors.

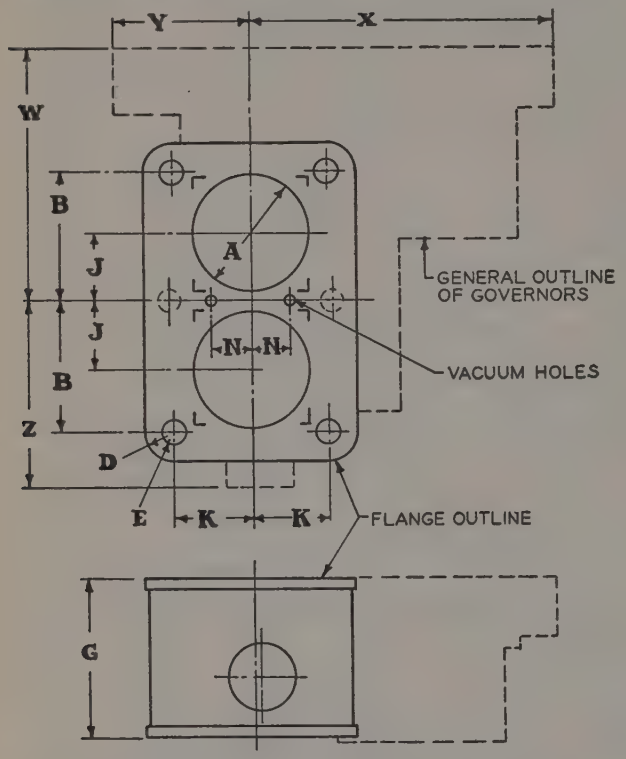


FIG. 3—DOUBLE-ORIFICE, 4-BOLT GOVERNOR FLANGE

TABLE 3—*Dimensions of Double-Orifice, 4-Bolt Governor Flanges*

	SAE FLANGE SIZE, IN.	
	1	1¼
Bore Size, *A*	1.125 x 1.146	1.140 x 1.287[a]
		1.187[b]
		1.502[c]
B	1.625	1.625
D	0.359	0.359
E	0.343	0.343
G	1.750	1.375[b]
		1.750[a]
		1.937[c]
J	0.687	0.719[b]
		0.758[a]
		0.796[c]
K	0.937	0.937
N	0.469	0.469
W (approx)	3.08	3.13
X (approx)	3.78	3.78
Y (approx)	2.81	2.81
Z (approx)	2.31	2.31

[a] These dimensions pertain to the same flange.
[b] These dimensions pertain to the same flange.
[c] These dimensions pertain to the same flange.

Normal Horsepower—The full-throttle brake horsepower output of the engine at any given speed without governor at the time and under the conditions of the governor tests.

Governor Cutoff Speed—The highest engine speed, obtained with the governor controlling, at which the brake horsepower output equals 95% of the normal horsepower for the same speed.

Governor Cuton Speed—The lowest engine speed at which the maximum horse-power is developed with the governor in operation while loading the dynamometer.

No-Load Speed—The highest engine speed, obtained with the governor controlling, at which the brake horsepower output equals 10% of the normal horsepower for the same speed.

Overrun—The maximum speed reached by a fully loaded engine upon sudden release of load with dynamometer switches open.

Hysteresis—The differential in speed, under any load, between the loading and unloading curves.

Governor Surge—A regular rise and fall in engine speed due to unstable governor control, occurring without manual throttle manipulation or external load change.

Regulation or Speed Droop—The speed differential between the no-load point and the cutoff or cuton point, whichever is lower.

Set Road Speed—The engine speed which the governor would maintain the wide-open carburetor throttle and with the engine installed in an unloaded vehicle operating on an approximately level, smooth highway at the road speed required.

Cheat—The increase in speed which can be obtained while the governor is controlling by suitable manipulation or positioning of the carburetor throttle or of the carburetor choke.

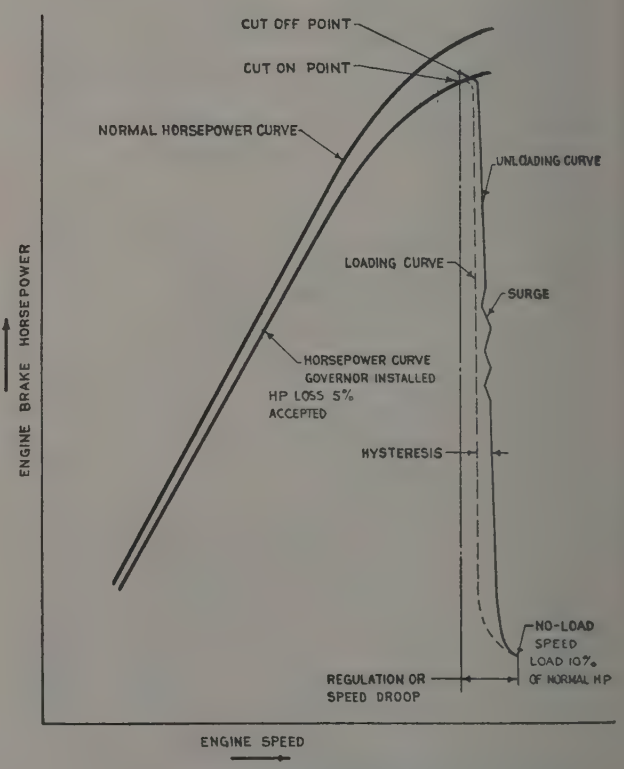


FIG. 4—TYPICAL LOADING AND UNLOADING CURVES FOR AIRFLOW-TYPE GOVERNORS

Automotive Carburetor Flanges

SAE Standard

Report of Carburetor Division approved June 1912 and last revised by Engine Technical Committee January 1951.

Since the original and previously revised SAE Standards were developed for throttle-body and air-cleaner flanges, industry has deviated from them to such an extent that, in many cases, a complete revision was necessary. The following standards were developed so as to include current carbureter flanges that are in production and to act as a guide for future designs. No attempt was made to list oval or special shaped connections.

To avoid possible confusion, the committee recommends that carbureter size be designated by the SAE size of the throttle flange and the *actual* throttle bore diameter. The two dimensions will be separated by a dash, as in 1¼—1 7/16 (1¼ SAE flange and a 1 7/16 actual throttle bore).

It is further recommended that the use of optional and special sizes be reduced to a minimum.

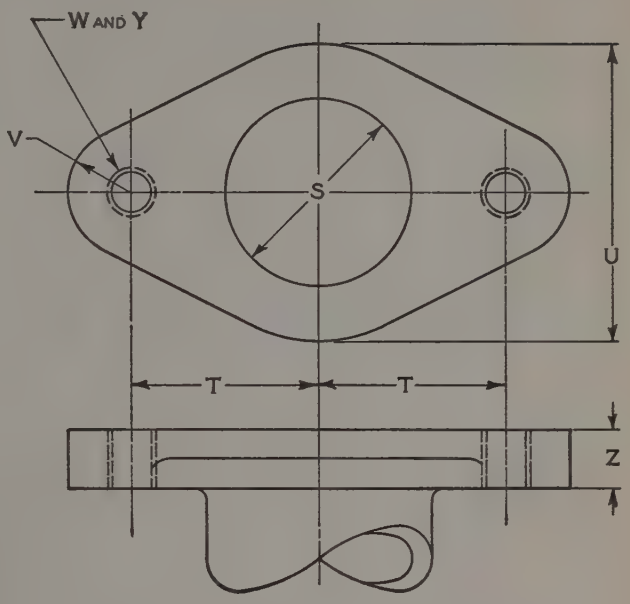


FIG. 1—SINGLE-BARREL THROTTLE-BODY FLANGE

TABLE 1—*Dimensions of Single-Barrel Throttle-Body Flanges*[a]

SAE CARBURETOR FLANGE SIZE	½	¾	1	1¼	1½	1¾	2
Actual bore size, *S*	0.812[d]	1.062[d]	1.312[d]	1.562[d]	1.812[d]	2.062	2.312
	0.750	1.000	1.250	1.500[d]	1.687[d]	1.937[d]	2.187[d]
	0.687	0.937[d]	1.187[d]	1.437[d]	1.562[d]	1.812[d]	2.062
	0.625	0.875	1.125	1.375	—	—	—
	0.562	0.812	1.062[d]	1.312	—	—	—
Attaching-hole centers[b], *T*	0.906	1.125	1.187	1.343	1.468	1.656	1.781
Flange width, *U*	1.437	1.750	1.875	2.187	2.500	2.812	3.125
Radius, *V*	0.281	0.343	0.343	0.406	0.406	0.468	0.468
Attaching-hole size, *W*	0.281	0.343	0.343	0.406	0.406	0.468	0.468
Attaching-hole tapping, *Y*	¼–20	5/16–18	5/16–18	3/8–16	3/8–16	7/16–14	7/16–14
Flange thickness[c], *Z*	0.312	0.312	0.375	0.375	0.375	—	—
Heavy-duty flange thickness[c], *Z*	0.312	0.312	0.375	0.406	0.468	0.500	0.562

[a] Dimensions specified are for cast-iron throttle bodies.
[b] For horizontal installations, the centerline of the attaching holes will be vertical plane.
[c] For aluminum throttle-body flange thickness, *Z*, use heavy-duty dimensions.
[d] These are preferred bore sizes which have been tested and are in production.

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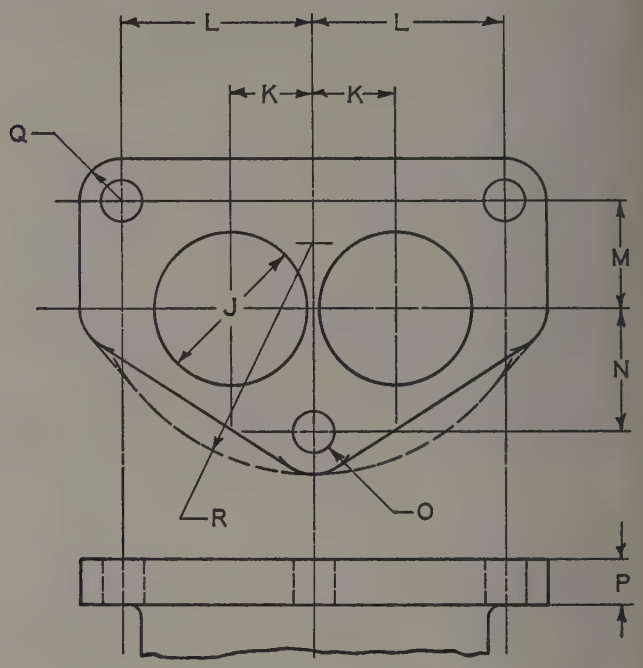

FIG. 2—3-BOLT DOUBLE-BARREL THROTTLE-BODY FLANGE

TABLE 2—*Dimensions of 3-Bolt Double-Barrel Throttle-Body Flanges*[a]

SAE CARBURETOR FLANGE SIZE	1[b]	1	1[b]	1[b]	1[b]	1[b]
Actual bore size, *J*	1.062	1.187	1.187	1.250	1.312	1.312
Bore centers, *K*	0.672	0.672	0.765	0.672	0.719	0.765
Attaching-hole centers, *L*	1.562	1.562	1.562	1.562	1.562	1.562
Attaching-hole centers, *M*	0.875	0.875	0.875	0.875	0.875	0.875
Attaching-hole centers, *N*	1.000	1.000	1.000	1.000	1.000	1.000
Attaching-hole size, *O*	0.343	0.343	0.343	0.343	0.343	0.343
Flange thickness[c], *P*	0.375	0.375	0.375	0.375	0.375	0.375
Heavy-duty-service flange thickness[c], *P*	0.437	0.437	0.437	0.437	0.437	0.437
Radius, *Q*	0.343	0.343	0.343	0.343	0.343	0.343
Radius, *R*	1.875	1.875	—	—	1.875	—

[a] Dimensions specified are for cast-iron throttle bodies. Larger 3-bolt sizes are not recommended.
[b] Optional bore and bore-center dimension.
[c] For aluminum throttle-body flange thickness, *P*, use heavy-duty dimension.

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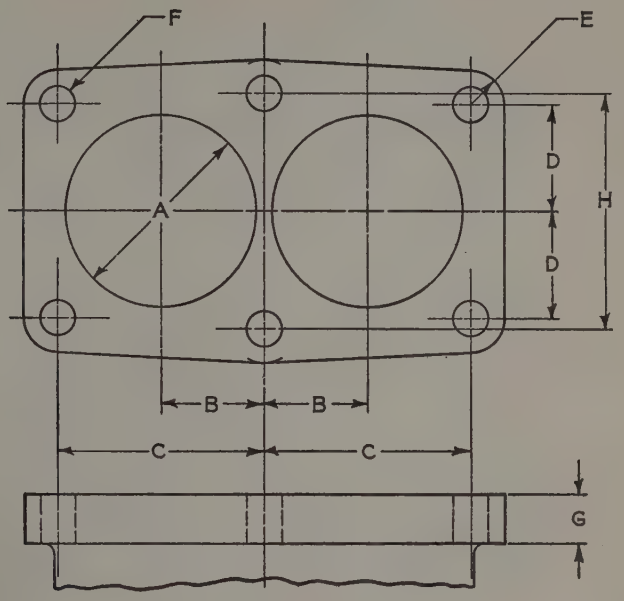

FIG. 3—DOUBLE-BARREL THROTTLE-BODY FLANGE

TABLE 3—*Dimensions of Double-Barrel Throttle-Body Flanges*[a]

SAE CARBURETOR FLANGE SIZE	1	1¼[b]	1¼[b]	1¼	1½	1¾[b]	1¾	2
Actual bore size, *A*	1.187	1.312	1.312	1.437	1.687	1.812	1.937	2.187
Bore center, *B*	0.719	0.719	0.797	0.797	0.937	1.062	1.062	1.187
Attaching-hole centers, *C*	1.500	1.625	1.625	1.625	1.843	2.062	2.062	2.375
Attaching-hole centers, *D*	0.812	0.937	0.937	0.937	1.000	1.250	1.250	1.218
Radius, *E*	0.359	0.359	0.359	0.359	0.359	0.390	0.390	0.390
Attaching-hole size, *F*	0.343	0.343	0.343	0.343	0.343	0.406	0.406	0.406
Flange thickness[c], *G*	0.375	0.406	0.406	0.406	0.437	0.500	0.500	0.562
Heavy-duty-service flange thickness[c], *G*	0.375	0.437	0.437	0.437	0.500	0.500	0.500	0.562
Attaching-hole centers, *H*	—	—	—	—	—	2.750	2.750	2.687

[a] Dimensions specified are for cast-iron throttle bodies.
[b] Optional bore and bore-center dimension.
[c] For aluminum throttle bodies, use heavy-duty flange-thickness dimension.

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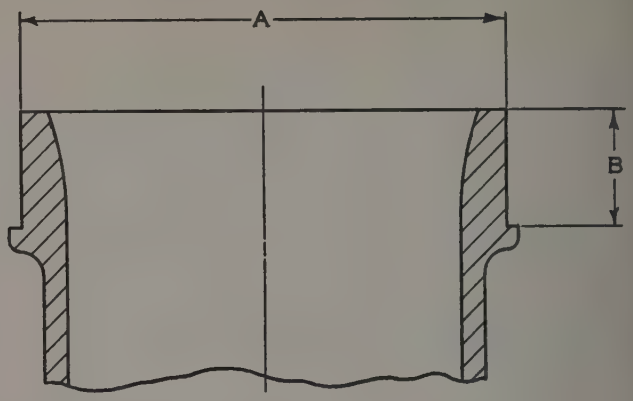

FIG. 4—TELESCOPE-TYPE AIR-HORN FLANGE

TABLE 4—*Dimensions of Telescope-Type Air-Horn Flanges*

Single-Barrel Carburetor

SAE CARBURETOR FLANGE SIZE	½	¾	1[a]	1	1¼	1½	1½[a]	1¾	2
Air-horn diameter, *A* (max to −0.010)	1.187	1.500	1.500	2.312	2.312	2.312	2.625	3.062	3.062
Clamp length[b], *B* ±0.015	0.500	0.625	0.625	0.625	0.625	0.625	0.625	0.750	0.750

Double-Barrel Carburetor

SAE CARBURETOR FLANGE SIZE	1	1¼
Air-horn diameter, *A* (max to −0.015)	2.625	2.625
Clamp length[b], *B*, ±0.015	0.625	0.625

Larger telescope-type flanges are not recommended.

[a] Optional size.
[b] For heavy-duty service and extended tube connection, add ¼ in. to *B*.

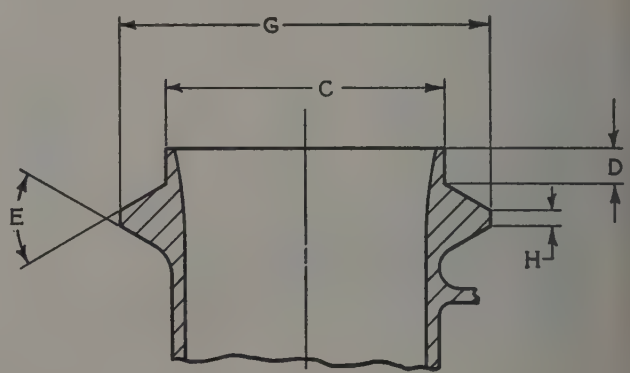

FIG. 5—V-CLAMP TYPE AIR-HORN FLANGE

TABLE 5—*Dimensions of V-Clamp Type Air-Horn Flanges*

	SINGLE-BARREL CARBURETOR								DOUBLE-BARREL CARBURETER				
SAE CARBURETOR FLANGE SIZE	¾	1[a]	1	1¼	1½	1½[a]	1¾	2	1	1¼	1¼[a]	1½	
Air-horn diameter, *C*	1.500	1.500	2.312	2.312	2.312	2.625	3.000	3.000	2.625	2.625	3.000	3.375	Not recommended for larger sizes.
Guide length, *D* (Min)	0.187	0.187	0.187	0.187	0.187	0.312	0.312	0.312	0.187	0.187	0.312	0.312	
Clamp angle, *E*, deg	60	60	60	60	60	60	60	60	60	60	60	60	
Outer-wedge diameter, *G*	2.000	2.000	2.812	2.812	2.812	3.125	3.500	3.500	3.125	3.125	3.500	3.875	
Width of clamp-angle face, *H*	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	

[a] Optional size.

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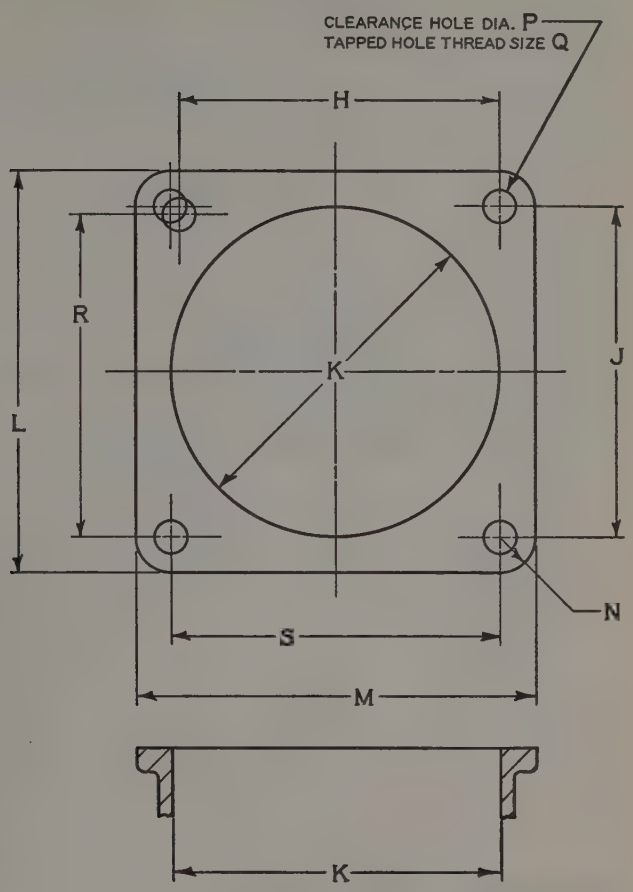


FIG. 6—SCREW-TYPE AIR-HORN FLANGE

TABLE 6—*Dimensions of Screw-Type Air-Horn Flanges*

	SINGLE-BARREL CARBURETOR					DOUBLE-BARREL CARBURETOR				
SAE CARBURETOR FLANGE SIZE	1	1¼	1½	1¾	2	1	1¼	1½	1¾	2
Bolt-center spacing, *H*	1.812	2.500	2.500	2.812	2.812	2.500	2.500	3.000	3.093	3.500
Bolt-center spacing, *J*	1.812	2.500	2.500	2.812	2.812	2.500	2.500	3.000	3.093	3.500
Air-opening diameter, *K*	1.625	2.562	2.562	2.812	2.812	2.500	2.500	3.000	3.000	3.500
Flange width, *L*	2.436	3.250	3.250	3.500	3.500	3.250	3.250	3.843	4.312	4.250
Flange width, *M*	2.436	3.250	3.250	3.500	3.500	3.250	3.250	3.843	4.312	4.250
Flange radius, *N*	0.312	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
Clearance-hole diameter, *P*	0.265	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343
Tapped-hole thread size, *Q*	¼–20	5/16–18	5/16–18	5/16–18	5/16–18	5/16–18	5/16–18	5/16–18	5/16–18	5/16–18
Bolt-center spacing[a], *R*	1.718	2.406	2.406	2.718	2.718	2.406	2.406	2.906	3.000	3.406
Bolt-center spacing[a], *S*	1.718	2.406	2.406	2.718	2.718	2.406	2.406	2.906	3.000	3.406

[a] Use bolt spacing *R* and *S* for one hole when relative cleaner position is required.

Carburetor Intakes

SAE Recommended Practice

Report of Engine Division approved March 1921.

The nominal diameter of the carburetor air intake shall be the inside diameter which shall vary by even quarter inches so as to take standard tubing sizes. This also applies to the outlet of carbureter air cleaners, air heaters, and similar devices wherever flexible metal tubing is used.

Carburetor Air-Horn Air-Cleaner Mounting

SAE Recommended Practice

Report of Engine Division approved August 1928.

TABLE 1—*Dimensions of Air-Cleaner Mountings*

A	*B*
0.750–0.740	5/8
1.125–1.115	3/4
1.500–1.490	7/8
1.624–1.614	7/8
1.812–1.802	3/4
2.062–2.052	1
2.312–2.302	1 1/8
2.625–2.615	1 1/2
3.125–3.115	1 3/4

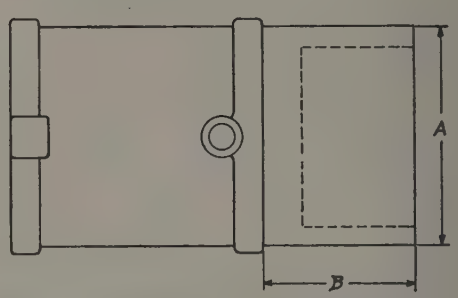


FIG. 1—CARBURETOR AIR-CLEANER MOUNTING

Fuel-Pump Mountings for Diaphragm-Type Pumps

SAE Recommended Practice

Report of Engine Division approved June 1929 and last revised by Gasoline Engine Division January 1941.

[The accompanying crankcase pads for mounting fuel pumps are for passenger cars, motorcoaches, trucks, and tractors.]

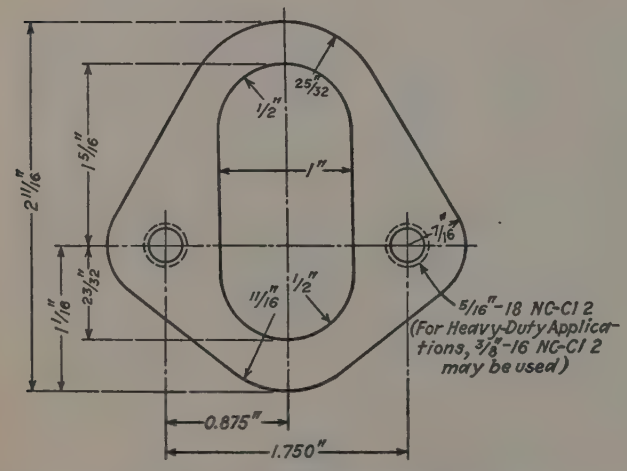


FIG. 1—PAD FOR PREFERRED TYPE
Where close clearances make it desirable, the preferred type may be used in position rotated 180 deg (inverted)

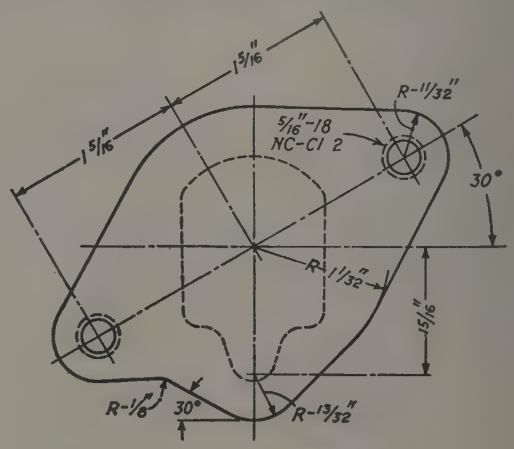


FIG. 2—PAD FOR ALTERNATE TYPE

Oil-Filter Mountings

SAE Standard

Report of Gasoline Engine Division approved June 1932.

[The accompanying dimensions are those of the pads provided on the engine. The connecting oil passages shall be located within the respective areas indicated.]

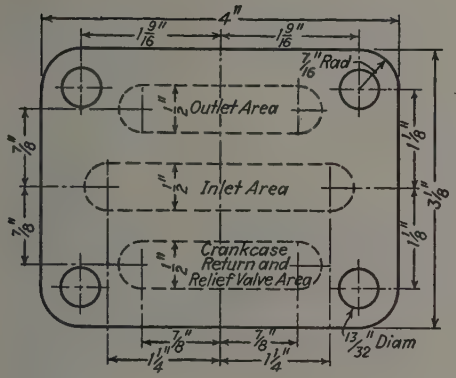


FIG. 1—SMALL TYPE

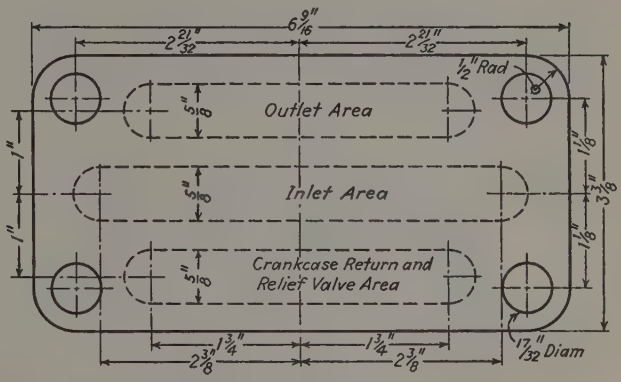


FIG. 2—DUAL TYPE

Radiator Nomenclature

SAE Standard

Report of Truck and Bus Technical Committee approved May 1949.

Radiator Cores—*Continuous Fin and Tube Core*—An assembly of fluid tubes of any cross-sectional form, the tubes being joined together by radiating fins or plates common to all tubes or groups of tubes.

Ribbon Cellular Core—A number of fluid passages made by joining metal ribbons at the edges and grouped to form a cellular structure. Parts of the cellular structure may be of formed or flat ribbon which is not a part of the fluid passages.

Corrugated Fin and Tube Core—An assembly of fluid tubes in line in the direction of airflow and joined in heat-transfer relation by corrugated conducting fins inserted between adjacent line of tubes.

Air-Tube Cellular Core—An assembly of air tubes nested so as to form fluid passages between the tubes, the passages being

sealed at the ends of the tubes. In this type, the fluid may flow transversely as well as vertically around the tubes.

Individual Fin and Tube—An assembly of fluid tubes of any cross-sectional form to each of which are attached gills or fins of circular, square, or other shape, each tube and its fin or fins forming a separate unit.

Left and right of a radiator is termed from the driver's seat or engine side.

Sheet-Metal Radiators—Figs. 1 and 2 illustrate the nomenclature for sheet-metal radiators.

Bolted Radiators—Figs. 3, 4, and 5 give the nomenclature for bolted radiators.

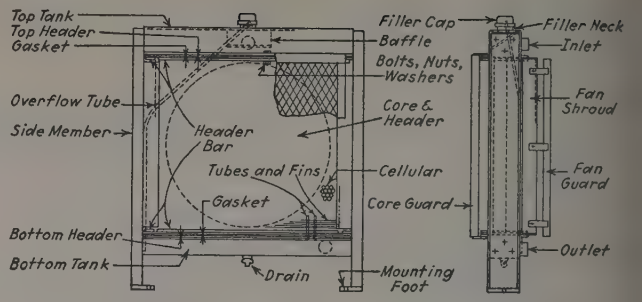


FIG. 3—CAST OR FABRICATED TYPE (ONE-PIECE CORE)

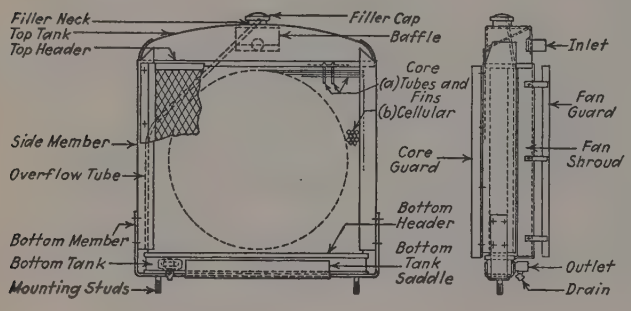


FIG. 1—SHEET-METAL TYPE

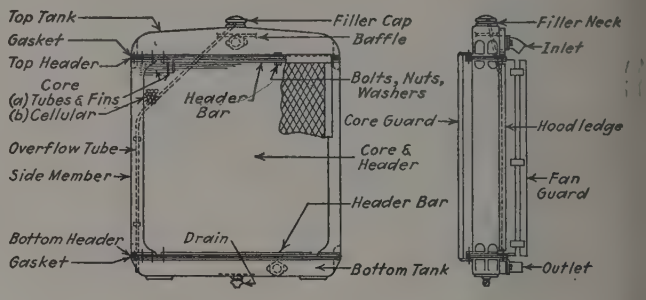


FIG. 4—CAST OR FABRICATED TYPE (ONE-PIECE CORE)

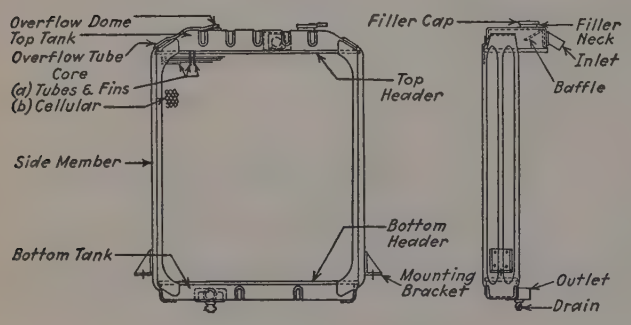


FIG. 2—SHEET-METAL TYPE

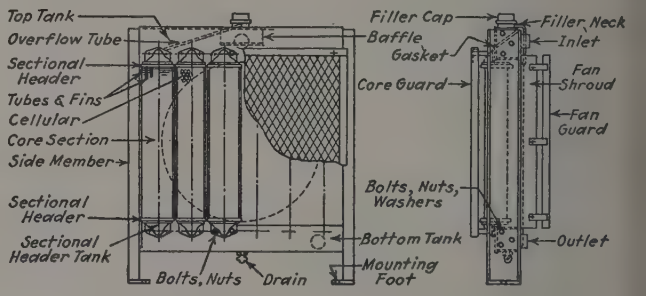


FIG. 5—CAST OR FABRICATED TYPE (SECTIONAL)

Water-Thermostat Pockets

SAE Standard

Report of Engine Technical Committee approved January 1951.

General—This standard is intended to eliminate unnecessary variations in the size of the cylinder-head water-outlet opening and the shape of the inlet opening in the water-outlet elbow. These specifications are considered adequate to meet all general-purpose requirements for both the "choke-type" thermostat pocket and the "by-pass-type" thermostat pocket.

Choke-Type Thermostat Pocket—Two sizes of pockets, the "flat flanged" and the "cupped flanged", Fig. 1 and 2, respectively, are for the popular choke-type thermostats. The former is considered typical for valve-in-head engines and the latter for L-head and T-head engines. The cupped-flanged pocket is considered standard for all pockets where the counterbore is designed into the pad of the water-outlet elbow.

By-Pass-Type Thermostat Pocket—This type of pocket is standardized in only one size and style as shown in Fig. 3. All other larger size or style by-pass pockets are considered special heavy duty or obsolete or both by the thermostat industry. Note that a $\frac{3}{32}$-in. vent hole (see Fig. 3) is common practice for diverting air and gases away from the pump and to the upper radiator tank.

Cluster-Type Thermostat Pocket—The use of two or more standard thermostat units in a cluster arrangement is considered

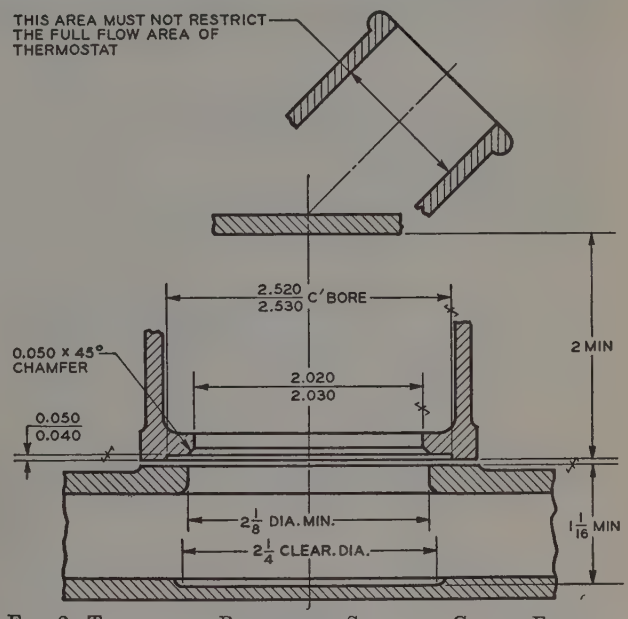

THIS AREA MUST NOT RESTRICT THE FULL FLOW AREA OF THERMOSTAT
2.520 / 2.530 C'BORE
0.050 x 45° CHAMFER
2.020 / 2.030
2 MIN
0.050 / 0.040
2 1/8 DIA. MIN.
2 1/4 CLEAR. DIA.
1 1/16 MIN

FIG. 2—THERMOSTAT POCKET FOR STANDARD CUPPED-FLANGED CHOKE THERMOSTAT

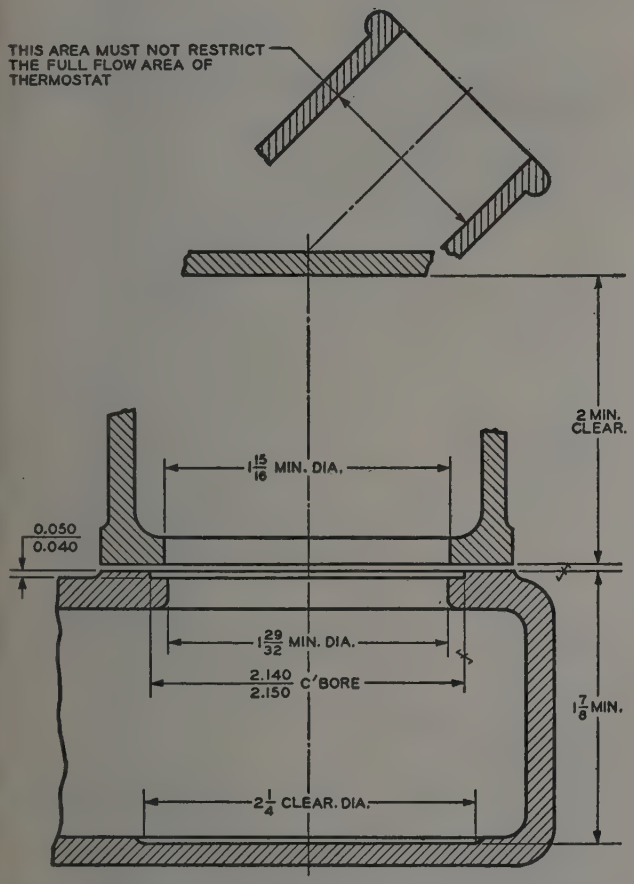

THIS AREA MUST NOT RESTRICT THE FULL FLOW AREA OF THERMOSTAT
2 MIN. CLEAR.
1 15/16 MIN. DIA.
0.050 / 0.040
1 29/32 MIN. DIA.
2.140 / 2.150 C'BORE
1 7/8 MIN.
2 1/4 CLEAR. DIA.

FIG. 1—THERMOSTAT POCKET FOR STANDARD FLAT-FLANGED CHOKE THERMOSTAT

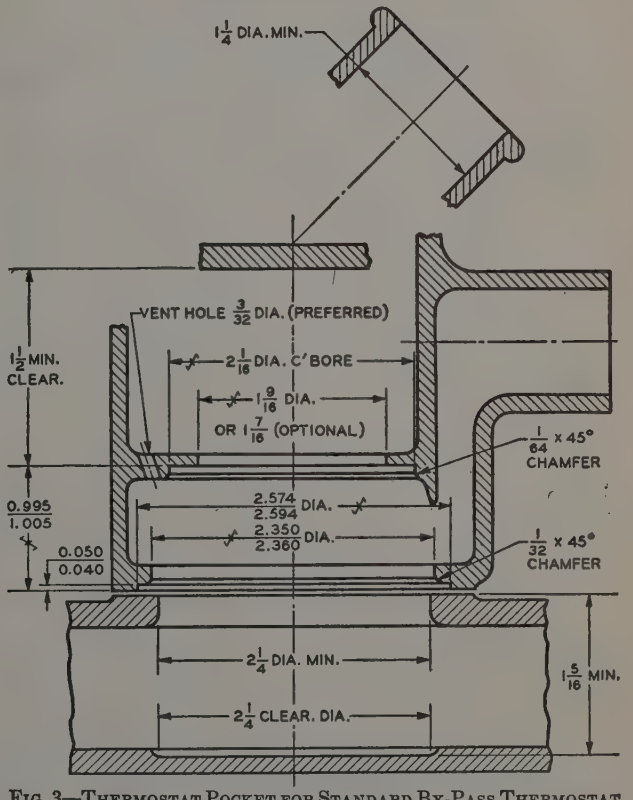


FIG. 3—THERMOSTAT POCKET FOR STANDARD BY-PASS THERMOSTAT

to be good practice. Such pockets should be in accord with the standardized pockets.

Clearance Diameter—The cylinder-head pocket shall be free of protruding ribs for hot-spot reasons, and all ribs in the cylinder-head water jacket should be designed parallel to the flow. Cross ribs are conducive to hot spots by virtue of their damming action.

Neck of Water Outlet Elbow—The neck should be of sufficient diameter to provide an area equal to the actual flow area of the thermostat and made to conform to the nearest larger standard-size hose connection.

Obsolete Pocket—The old practice of installing the thermostat in the water-outlet elbow by means of retaining rings or springs is considered undesirable for the reason that it fails to provide positive assurance against excessive leakage around the thermostat, especially when replacement of damaged or disintegrated retainers is neglected.

Fan-Hub Bolt-Circles and Pilot Holes

SAE Recommended Practice

Report of Engine Technical Committee approved January 1951.

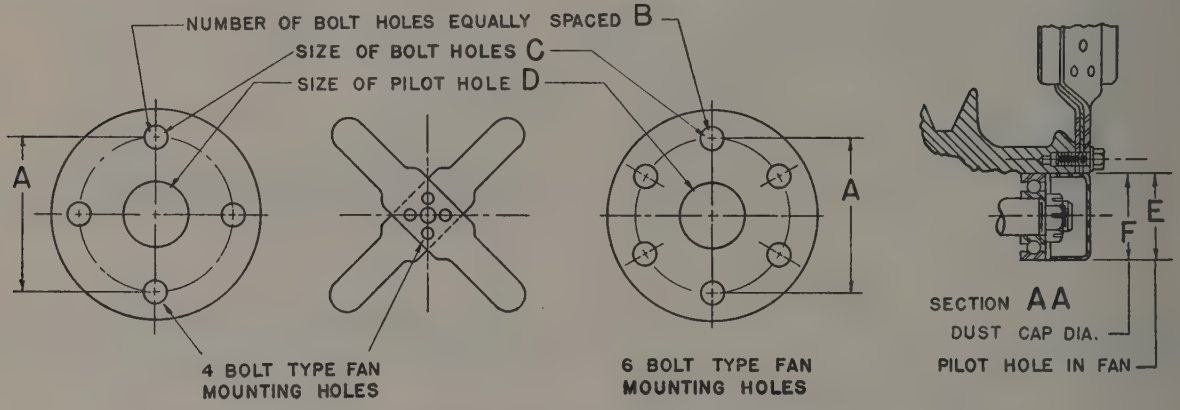


TABLE 1—*Standard Mounting Dimensions for Cooling Fans of Internal-Combustion Engines*

FAN DIAMETER	BOLT-HOLE-CIRCLE DIAMETER *A*	NUMBER OF BOLT HOLES, *B*	SIZE OF BOLT HOLES, *C*	SIZE OF FAN PILOT HOLE, *D*	SIZE OF HUB OR SHAFT	SIZE OF PILOT HOLE FOR DUST CAP, *E*	SIZE OF DUST CAP AS PILOT, *F*	USED ON
16 to 19 inclusive	1.75 ± 0.005	4	0.340 ± 0.010	0.6287 0.6277	0.6267 0.6262	—	—	Bearing-shaft pilot
	1.75 ± 0.005	4	0.340 ± 0.010	0.7525 0.7515	0.751 0.750	—	—	Bearing-shaft pilot
	1.75 ± 0.005	4	0.340 ± 0.010	1.002 1.000	0.998 0.996	—	—	Hub pilot
20 to 24, inclusive	2.50 ± 0.005	4	0.385 +0.015 −0.000	1.502	1.498	1.859	1.855	Hub pilot, dust-cap pilot, E and F
		6	0.385 +0.015 −0.000	1.500	1.496	1.856	1.852	
25 to 28, inclusive	3.50 ± 0.005	4	0.510 +0.015 −0.000	2.002	1.998	2.059	2.052	Hub pilot, dust-cap pilot, E and F
		6	0.385 +0.015 −0.000	2.000	1.996	2.056	2.049	
29 to 36, inclusive	4.50 ± 0.005	4	0.510 +0.015 −0.000	2.503	2.498	2.448	2.444	Hub pilot, dust-cap pilot, E and F
		6	0.385 +0.015 −0.000	2.500	2.496	2.445	2.442	

V-Belts and Pulleys

SAE Standard

Report of Miscellaneous Division approved August 1915 and last revised by Engine Technical Committee January 1951.

[*This specification was first formulated with the cooperation of a V-belt committee appointed by the Rubber Manufacturers Association. The belts and pulleys specified are intended primarily for automotive applications such as fan, generator, and pump drives; and where the load capacity of a single standard belt is inadequate, the required capacity can usually be obtained by using standard belts and pulleys in multiple.*]

Recommended Method of Making V-Belt Drive Layouts—It is very desirable to make the pulley diameters as large as possible without exceeding 7000-fpm belt speed. Pulley diameters should never be smaller than shown in Table 1.

Pulleys should be laid out in the positions desired (Fig. 2) when a new belt is applied and first brought to driving tension. The adjustable pulley should be movable back from the initial desired running position by an amount equal to the belt thickness to facilitate applying the belt. If such allowance is not provided, the belt may be injured by prying it on over the side of the pulleys. The adjustable pulley should also be movable in the other direction sufficiently to take up at least 2½% of the belt circumferential length in addition to the allowance for applying the belt.

The contour of the belt will then be given by the tangents and connecting circles ⅛ in. larger in diameter than the outside diameter of the pulleys.

Insert pins every ¾ in. on the curved portions of the belt contour, and measure the length over these pins with a flexible ¼-in. steel tape. This method is accurate to about 1/32 in., and the length so determined may be used for selecting the original sample belt.

The included angle of the belt shall be determined by the belt manufacturer to meet the specific requirements of each belt-drive application.

Method of Checking V-Belts—Length of V-belts shall be

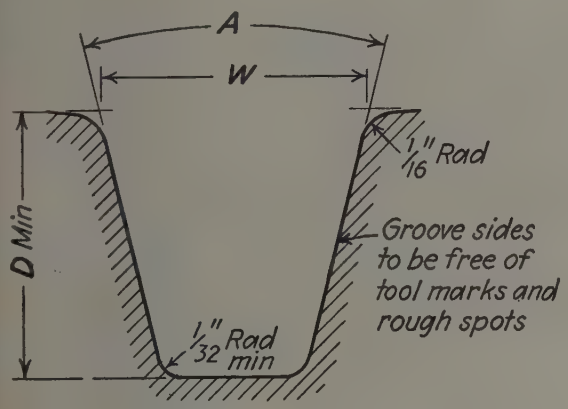


FIG. 1—V-BELT PULLEY GROOVE

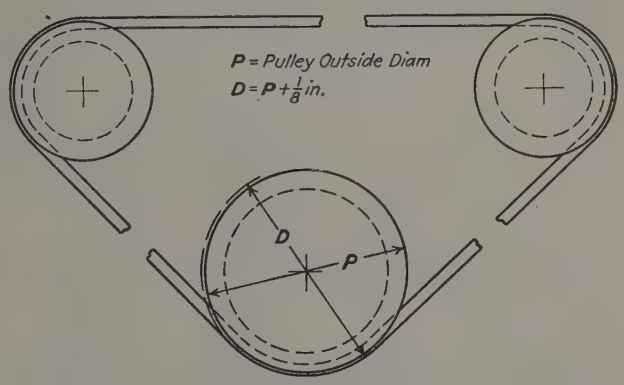


FIG. 2—V-BELT LAYOUT FOR MEASURING BELT LENGTHS

TABLE 1—*V-Belt and Pulley Dimensions* (*See Fig. 1*)

SAE SIZE AND NOMINAL TOP WIDTH, IN.	NOMINAL BELT THICKNESS, IN.	PULLEY OUTSIDE DIAMETER, IN., ±0.010	GROOVE DIMENSIONS		
			Top width, *W*, in., ±0.010	Angle *A*, deg, ±½ deg	Minimum depth, *D*, in.
5/8	3/8	3 and larger	0.625	28	19/32
11/16	13/32	3 to 4 in. incl[a]	0.625	34	5/8
		Over 4 to 6 in. incl		36	
		Over 6 in.		38	
¾	7/16	3 to 4 in. incl[a]	0.688	34	11/16
		Over 4 to 6 in. incl		36	
		Over 6 in.		38	
⅞	½	3½ to 4½ in. incl[a]	0.813	34	13/16
		Over 4½ to 6 in. incl		36	
		Over 6 in.		38	
1	9/16	4 to 6 in. incl[a]	0.938	34	15/16
		Over 6 to 8 in. incl		36	
		Over 8 in.		38	

[a] *Caution:* in designing V-belt drives, it must be borne in mind that these small-diameter pulleys should be used only in extreme cases and that the power-transmitting capacity and belt life are materially reduced when they are used.

measured on a standard fixture[1] with the belt mounted on two 4¾-in. outside diameter pulleys (Fig. 3) under tensions as follows:

Belt Size, In.	*Tension, Lb*
⅝ and 11⁄16	60
¾	80
⅞	100
1	120

The groove in the pulleys (Fig. 1, *W*) shall be 34 deg included angle and 15⁄16 in. wide at the top.

After applying tension to the belt the pulleys should be rotated at least one turn to seat the belt or they may be rotated continuously at slow speed.

Belt length shall be designated as the outside length of the belt. Lengths shall be checked by the center-to-center distance of the pulleys on the fixture with a tolerance of plus or minus ⅛ in., in accordance with the length formulas stamped on the notched pulley shown in Fig. 3. The original center-to-center distance on the fixture shall be determined by an original sample belt of correct length.

Belt Ride-Out—The ride-out of the belt shall be 1⁄16 in. plus or minus 1⁄32 as measured from a straightedge across the top of the belt to the bottom of the proper notch (Fig. 3) in the fixture pulley.

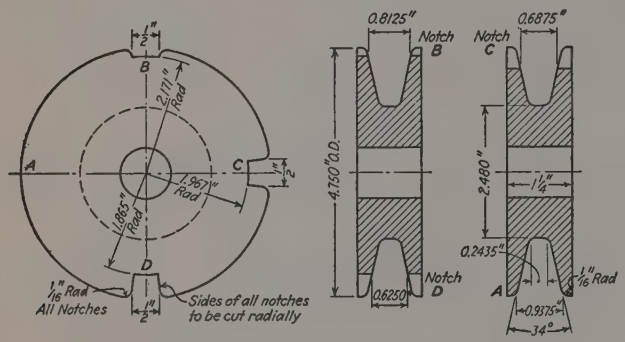


FIG. 3—NOTCHED PULLEY FOR TESTING FIXTURES

Notched Pulley—The notched pulley is to be stamped as follows:

Stamp at *A*—SAE 1 in., belt length = 2 × (c to c) + 15.315 in.
at *B*—SAE ⅞ in., belt length = 2 × (c to c) + 14.033 in.
at *C*—SAE ¾ in., belt length = 2 × (c to c) + 12.751 in.
at *D*—SAE ⅝ and 11⁄16 in., belt length = 2 × (c to c) + 12.110 in.

Two pulleys are to be used on each testing fixture, one to be notched as shown in Fig. 3 and the other without notches.

Designation of Belt Size—Belts shall be specified and marked by SAE size number and the center-to-center distance in inches between the pulleys, as established on the testing (checking) fixture.

0.380-In. and 0.500-In. V-Belts and Pully Grooves

Grooves—The pulley grooves shall conform to the dimensions given in Fig. 4 and Table 2.

[1] The layout for a suitable testing fixture, SAE drawing 7-7-10, may be obtained from the Society at nominal cost.

Method for Measuring Belt Length—For measuring length, two pulleys, each 3.820 in. nominal diameter for 0.380-in. belts and for 0.500-in. belts, shall be used. The pulleys shall conform to the groove standard except that the 0.06 radius shall be omitted, the diameter and groove width tolerances shall be ±0.0005, and the groove angle shall be 36 deg ± 5 min. The measuring tension shall be 60 lb (30 lb on each strand of belt) for 0.380-in. belts and for 0.500-in. belts. After rotating the belt by hand, the center distance shall be measured. Twice the center distance plus 12 in. for 0.380-in. and 0.500-in. belts shall be taken as the SAE length of the belt.

Standard Lengths—Standard lengths shall be in 1-in. increments without fractions up to and including 60 in. Above 60 in., the increments shall be 2 in. without fractions. It is recognized that some belt layouts may require intermediate lengths.

Length Tolerances—The standard length tolerances shall be ±⅛ in. on centers for belts up to but not including 50 in.; ±3⁄16 in. on centers for 50 in. to 60 in., both inclusive; ±¼ in. on centers for lengths over 60 in. to 80 in., inclusive.

TABLE 2—*Dimensions of 0.380-In. and 0.500-In. Pulley Grooves*

W	*D* (MIN)	*d* (BALL DIAMETER)	*K*	2*K*
0.380	0.430	0.3125	0.077	0.154
0.500	0.562	0.4375	0.157	0.314

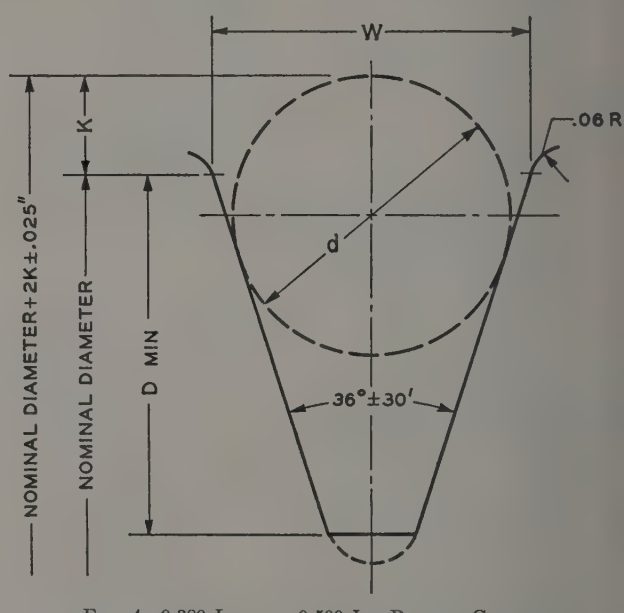


FIG. 4—0.380-IN. AND 0.500-IN. PULLEY GROOVE

Note 1—The sides of groove shall be smooth.

Note 2—Radial run-out shall not exceed 0.015, total indicator reading. Lateral run-out shall not exceed 0.015, total indicator reading. Run-out in the two directions shall be measured separately as total indicator readings of movement of ball mounted under spring pressure to follow groove as pulley is rotated. Diameter, load, and over-hang conditions may require or permit variations in the above specified run-out limits.

Note 3—Bottom corner radii optional, but if used, it shall be below the depth, *D*.

Note 4—In pulleys for use with belts in multiple on common centers, the diameters over the ball gages shall not vary more than 0.005 in. from groove to groove in the same pulley.

Note 5—Centerline of groove shall be 90 deg ± 2 deg with pulley axis.

Power Take-Off

SAE Standard

Report of Transmission and Truck Division approved August 1919 and last revised by Motorcoach and Motor Truck Technical Committee March 1949.

The accompanying mounting and gear locations are applicable for all general installations of power take-off on the transmission-gear box of motor trucks and tractors where the size of the transmission permits. The adapter plate shown for the 8-bolt mounting allows the use of power take-offs designed for the standard 6-bolt aperture.

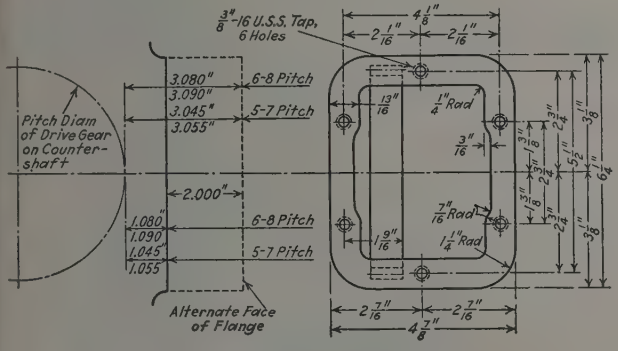


Fig. 1—Regular-Duty Type

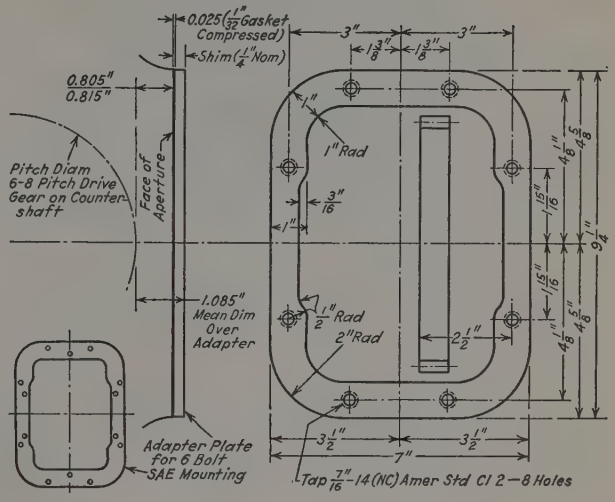


Fig. 2—Heavy-Duty Type

Hydrodynamic-Drive Terminology

SAE Recommended Practice

Report of Hydrodynamic Drive Technical Committee approved January 1951.

[*Since the torque converter and fluid coupling have become a commonly used component of automatic transmissions in American industry, the SAE appointed a committee to standardize terminology, test procedure, data recording, design symbols, and so forth in this field. The following committee recommendations will facilitate a clear understanding for engineering discussions, comparisons, and the preparation of technical papers.*

Practice in industry at present is not uniform. The recommended usages represent the predominating practice or the acceptable practice. Where agreement is not complete, alternates have been included for clarification. For example, three systems of blade-angle designations are described. Consequently when a blade angle is specified, the system should be designated.

This SAE Recommended Practice deals only with the physical parts and dimensions and does not attempt to standardize the design considerations, such as the actual fluid flow angle resulting from the physical blade shape.]

Hydrodynamic drive, as contrasted with electrical or mechanical and so forth, is the type of drive that transmits power solely by dynamic fluid action in a closed recirculating path.

Fluid coupling is a hydrodynamic drive which transmits power without ability to change torque. (Torque ratio is unity for all speed ratios.) See Fig. 1.

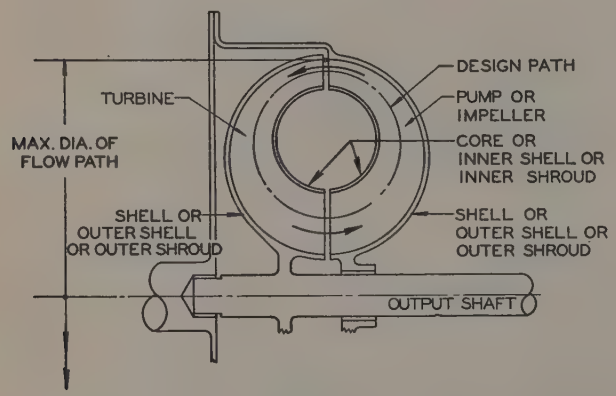

DESIGN PATH
TURBINE
PUMP OR IMPELLER
MAX. DIA. OF FLOW PATH
CORE OR INNER SHELL OR INNER SHROUD
SHELL OR OUTER SHELL OR OUTER SHROUD
SHELL OR OUTER SHELL OR OUTER SHROUD
OUTPUT SHAFT

FIG. 1—FLUID COUPLING

Torque converter is a hydrodynamic drive which transmits power with ability to change torque. (Torque ratio is a function of speed ratio.) See Figs. 2–5.

Stage (single-stage, two-stage, three-stage) applied to a torque converter refers to the number of driven members separated from each other by members of different function such as stators or input members. See Figs. 2 and 3.

Phase (single-phase, two-phase, polyphase) applied to a torque converter refers to the number of functional arrangements of the working members when the functional change is by mechanical means; for example, a stator which may free-wheel in one direction. See Figs. 4 and 5.

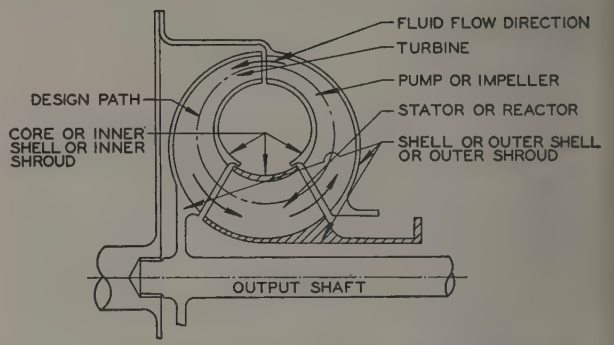


FIG. 2—SINGLE-PHASE, SINGLE-STAGE TORQUE CONVERTER

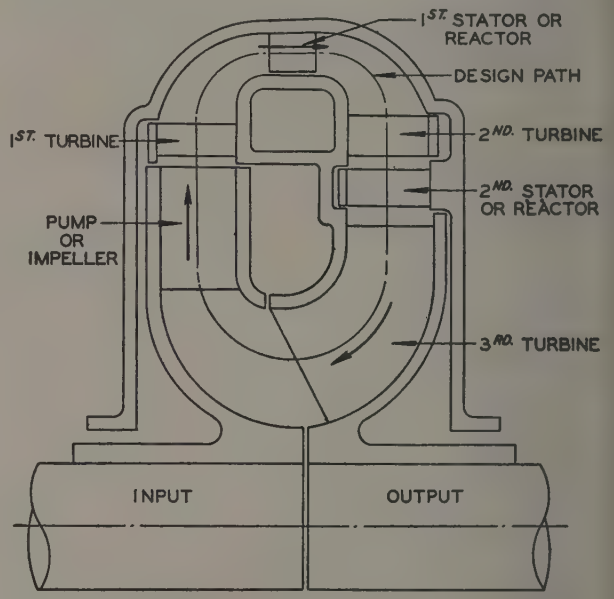


FIG. 3—SINGLE-PHASE, THREE-STAGE TORQUE CONVERTER

Member refers to a functional component of the hydrodynamic drive such as a pump, turbine, or stator.

Pump or **impeller** designates the power-input member.

Turbine designates the output member.

Stator or **reactor** designates the reaction member.

Nomenclature of multiple members of basically the same function in both polyphase and multistage torque converters should be named in the order of fluid circulation in normal operation.

first pump	first turbine	first stator
second pump	second turbine	second stator
and so forth	and so forth	and so forth

(*Continued on next page.*)

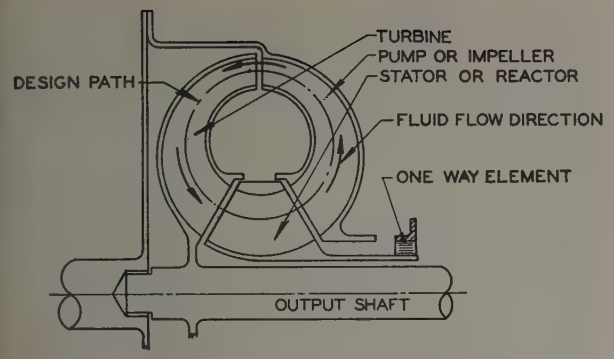


FIG. 4—THREE-MEMBER TWO-PHASE TORQUE CONVERTER

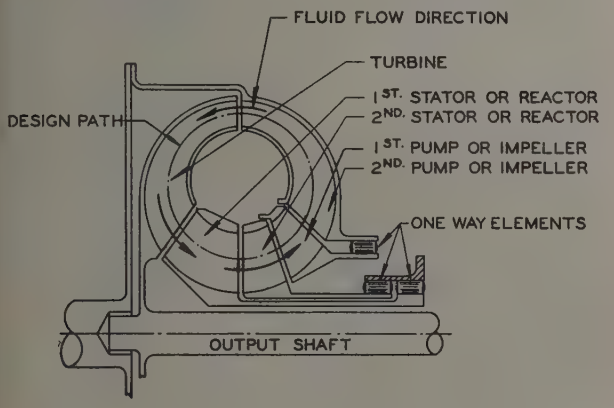


FIG. 5—FIVE-MEMBER POLYPHASE TORQUE CONVERTER

Blade designates the element of a member upon which the fluid exerts working force.

Shell, outer shell, or **outer shroud** designates the outside wall of the toric fluid path in any member. See Figs. 1 and 2.

Core, inner shell, or **inner shroud** designates the inside wall of the toric fluid path in any member. See Figs. 1 and 2.

Design path is the path of the assumed mean effective flow and is used for definition of blade angles, entrance and exit radii, and so forth. See Figs. 1–6.

Bias (entrance and exit) designates the angular discrepancy at the entering and leaving edges of the blades, where the full length of the entering and leaving edges of the blades are not in an axial plane (contains the axis of rotation). See Fig. 6.

Scroll is the angle between the two planes containing the intersection of the design path and the entering and leaving edges of the blade when that blade does not lie in one axial plane. See Fig. 6.

Torque converter size in general terms is designated by the maximum diameter in inches of the flow path. See Fig. 1.

Design radii (entrance or exit) of any member are taken at the point of intersection of the design path with the theoretical blade edges. See Fig. 6.

Speed ratio designates the output speed divided by the input speed.

Torque ratio designates the output torque divided by the input torque.

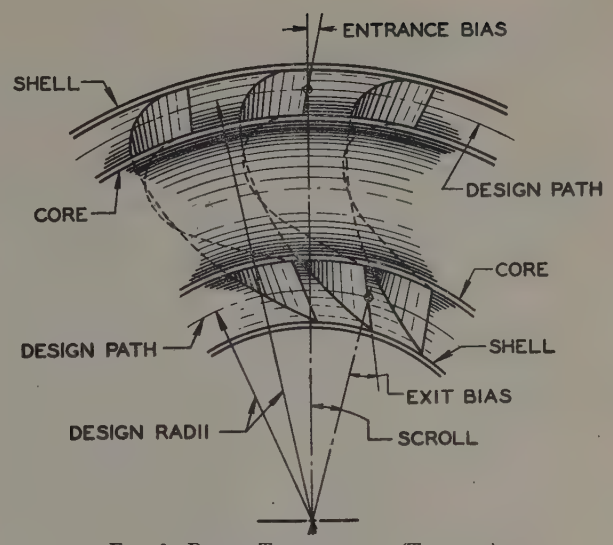


FIG. 6—BLADE TERMINOLOGY (TURBINE)

Stall torque ratio designates the torque ratio with a stalled turbine.

Stall speed designates the input speed in rpm with a stalled turbine at a specified input torque.

Racing speed designates the input speed in rpm with a free turbine at a specified input torque.

Torque conversion range designates the range of operation where torque multiplication exists.

Coupling range designates the range of operation at 1 to 1 torque ratio.

Coupling point designates the point where the torque conversion range ends and the coupling range begins.

Charging pressure designates the externally applied pressure under which the converter operates.

Blade angles are the angles formed by the geometry of a blade at its entrance and exit edges. Unless otherwise mentioned, these angles are measured from a tangent to a point on the design path surface. When a blade angle is not constant across the width of a blade, specific mention must be made of the manner of variation.

Mean camberline of a blade profile, taken at the intersection of the design path surface, is the locus of the centers of the series of circles which are simultaneously tangent to both surfaces of the blade profile. See Fig. 7.

This method of mean camberline determination is shown for a

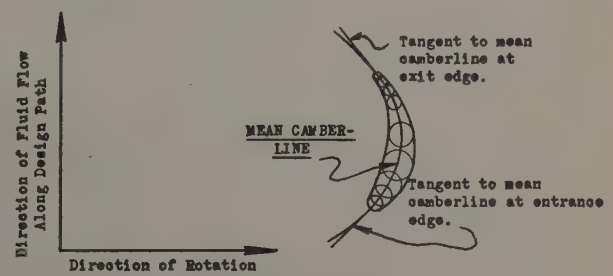

Direction of Fluid Flow Along Design Path
Direction of Rotation
MEAN CAMBER-LINE
Tangent to mean camberline at exit edge.
Tangent to mean camberline at entrance edge.

FIG. 7—DEVELOPED SECTION OF BLADE AT INTERSECTION WITH DESIGN PATH SURFACE

continuously varying double surface type of hydrofoil. The same system is to be used for all other types of blade profiles, including cases where discontinuities arise, because of edge modifications, as with sheet-metal blades.

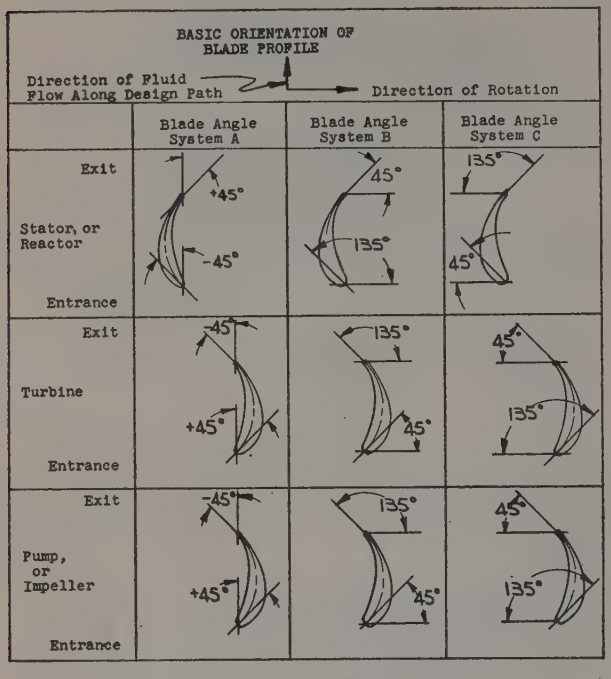


FIG. 8—ANGLE SYSTEMS

Entrance angles and **exit angles** are measured as the angles between the respective tangents to the mean camberline of the blade and a plane perpendicular to, or parallel with, the plane of rotation (depending on the system of measurement used—that is, System A, or Systems B and C, respectively, as hereafter described.)

Blade-angle systems are the systems used for systematically and consistently describing blade angles. There are three currently used blade angle-systems. See Fig. 8.

System A takes zero blade angles to have no backward or forward bend: That is, all angles are measured from a plane of reference which passes through the axis of rotation. Blade angles which have a component in the direction of rotation are taken as positive. Blade angles which have a component opposite to the direction of rotation are taken as negative. Trigonometric functions of their angles, as used in torque-converter design, derive their plus or minus sign from the above rules.

System B takes zero blade angles to have the maximum possible forward bend angle in the pump: That is, all angles are measured from a plane of reference, which is the plane of rotation. All blade angles are positive. Trigonometric functions of these angles, as used in torque-converter design, derive their plus or minus sign from the trigonometric tables in their proper quadrants.

System C takes zero angle as the maximum possible back bend on the pump. This system is the exact reverse of System B.

Hydrodynamic-Drive Laboratory Test Code

SAE Standard

Report of Hydrodynamic Drive Technical Committee approved January 1951.

[This test code is intended for laboratory use in determining the primary operating characteristics of hydrodynamic drives of a type and capacity applicable to motor-vehicle installations. There are five test-code forms:

Form H—Direction sheet.

Form HA—Log sheet.

Form HB—Curve sheet for plotting input speed, torque ratio, input torque, capacity factor, and efficiency against speed ratio.

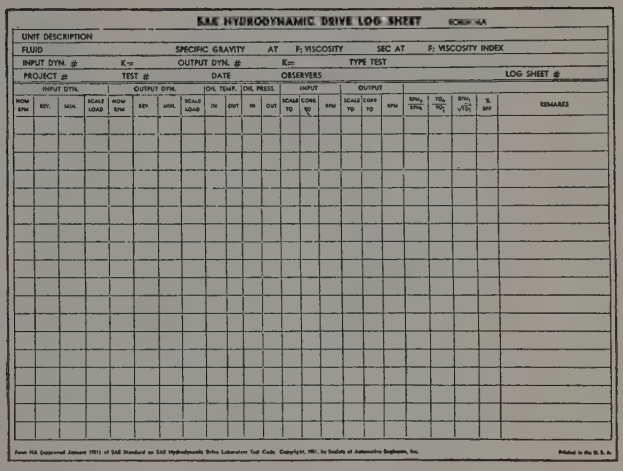
Form HC—Curve sheet for plotting turbine speed, torque ratio, turbine torque, and capacity factor against speed ratio.

Form HD—Curve sheet for plotting input speed, input torque, torque ratio, efficiency, and speed ratio against output speed.

Forms HB, HC, and HD have the grid printed in green on the back of the sheet, so that erasures of datum points will not destroy the grid. The paper is sufficiently transparent to show the grid through to the face of the sheet and to reproduce well.

The Society sells the forms individually as well as in sets. Figs. 1–5 are small-scale reproductions of the forms.

Forms H, HA, HB, and HC are printed on 8½ x 11-in. sheets. Form HD is printed on 11 x 16½-in. sheet.]


SAE HYDRODYNAMIC DRIVE LOG SHEET

UNIT DESCRIPTION

FLUID SPECIFIC GRAVITY AT F; VISCOSITY SEC AT F; VISCOSITY INDEX

INPUT DYN. # K= OUTPUT DYN. # K= TYPE TEST

PROJECT # TEST # DATE OBSERVERS LOG SHEET #

INPUT DYN.				OUTPUT DYN.				OIL TEMP.		OIL PRESS.		INPUT		OUTPUT						REMARKS
ROW RPM	REV.	MOM.	SCALE LOAD	ROW RPM	REV.	MOM.	SCALE LOAD	IN	OUT	IN	OUT	SCALE TQ	CORR. TQ	SCALE TQ	CORR TQ	RPM				

Form HA (approved January 1951) of SAE Standard on SAE Hydrodynamic Drive Laboratory Test Code. Copyright, 1951, by Society of Automotive Engineers, Inc. Printed in the U. S. A.

Fig. 2—Form HA, Log Sheet

SAE HYDRODYNAMIC DRIVE LABORATORY TEST CODE

DIRECTION SHEET — FORM H

Scope

This test procedure is intended for laboratory use in determining the primary operating characteristics of hydrodynamic drives of a type and capacity applicable to motor-vehicle installations. It is not intended to cover the many special tests which may be required at various times, such as centrifugal bursting tests or heat-rejection tests.

The primary characteristics to be determined are:

1. Torque ratio versus speed ratio.
2. Input speed versus speed ratio.
3. Efficiency versus speed ratio.
4. Capacity factor versus speed ratio.
5. Torque ratio, speed ratio, input speed, input torque, and efficiency versus output speed.

Apparatus

1. Double dynamometer test stand with instrumentation for reading torque within ± ½% of full-load torque, and for reading speed within ± 5 rpm.

2. An independent operating-fluid supply system with provisions for pumping, heating, cooling, and regulating the flow of the fluid.

3. Instrumentation for measuring temperature and pressure of the fluid at the hydrodynamic drive.

4. Fluid of known physical and chemical characteristics. This fluid should be the same as that intended for use in the vehicle.

Procedure

The hydrodynamic-drive tests are to be run on a double dynamometer test stand, giving accurate measurements of the speeds and torques of the input and output shafts of the hydrodynamic drive.

Before starting the primary hydrodynamic-drive tests, calibration curves should be run on both dynamometers, the headstand, and on the torque- and speed-indicating instruments.

The tests are divided into three major classifications:

1. Predetermined input conditions:
   (a) Constant input torque with varying input and output speeds.
   (b) Constant input speed with varying input and output torques and varying output speed.
   (c) Input speed and torque equivalent to that of a selected engine torque curve, with a varying output speed. (The selected engine torque curve should be the actual net torque of the engine as installed in the vehicle.)

2. Varying input speed and torque with output speed and torque corresponding to road-load requirements for a particular vehicle.

3. Coast drive test with the turbine driving to simulate closed-throttle coasting conditions. Vary the turbine speed in constant increments and adjust the pump speed and torque to an engine friction torque curve.

The above tests should be conducted at specified fluid temperatures (100-300 F range) and at specified fluid or charging pressures within the unit corresponding to actual conditions expected in vehicle operation. All readings should be taken simultaneously with loads, speeds, temperatures, and pressures stabilized where possible. Where such stabilization is not possible, the time interval between readings or the rate of change must be noted.

Presentation of Results

1. Completely identify hydrodynamic unit which was tested, and record test conditions, on all data and curve sheets.

2. Develop performance curve diagrams by calculating and plotting torque ratio, efficiency, and capacity factor characteristics versus speed ratio or output speed after correcting observed dynamometer data for instrument calibrations and equipment tare.

3. Include copies of or identify all data sheets with report of results.

Form H (approved January 1951) of SAE Standard on SAE Hydrodynamic Drive Laboratory Test Code. Copyright, 1951, by Society of Automotive Engineers, Inc. Printed in the U. S. A.

Fig. 1—Form H, Direction Sheet

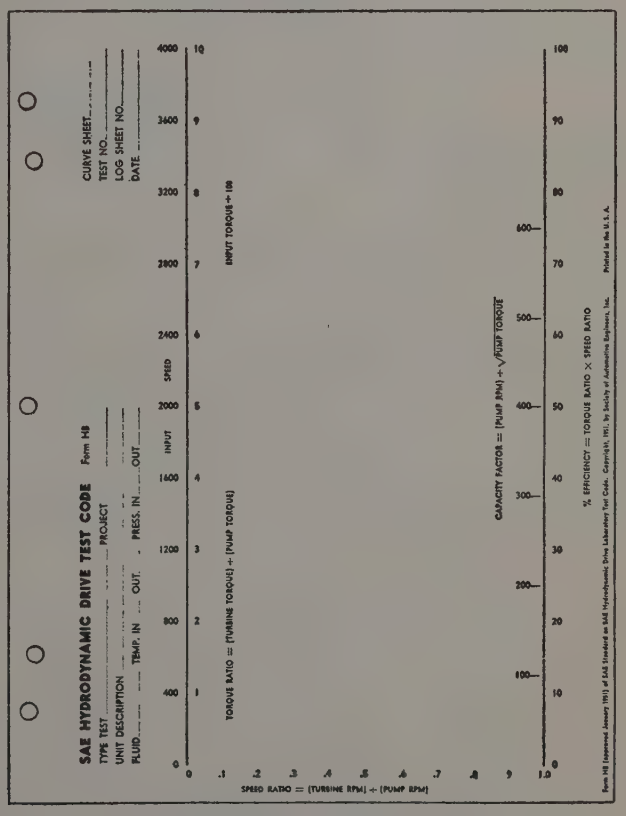

SAE HYDRODYNAMIC DRIVE TEST CODE Form HB
TYPE TEST
UNIT DESCRIPTION
FLUID TEMP. IN OUT PRESS. IN OUT
PROJECT
CURVE SHEET
TEST NO.
LOG SHEET NO.
DATE
SPEED
INPUT
INPUT TORQUE ÷ 100
TORQUE RATIO = (TURBINE TORQUE) ÷ (PUMP TORQUE)
CAPACITY FACTOR = (PUMP RPM) ÷ √PUMP TORQUE
% EFFICIENCY = TORQUE RATIO × SPEED RATIO
SPEED RATIO = (TURBINE RPM) ÷ (PUMP RPM)
Form HB (approved January 1951) of SAE Standard on SAE Hydrodynamic Drive Laboratory Test Code. Copyright, 1951, by Society of Automotive Engineers, Inc.
Printed in the U. S. A.

Fig. 3—Form HB, Curve Sheet

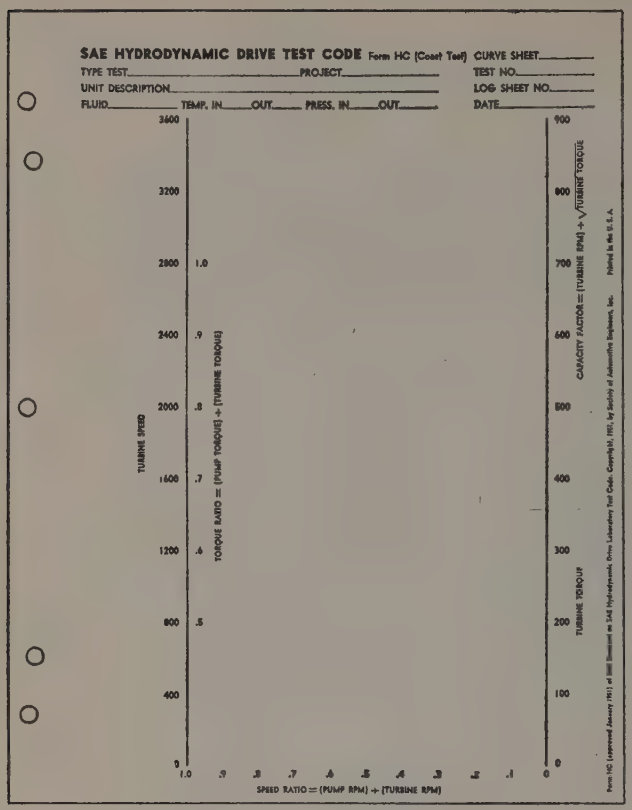


FIG. 4—FORM HC, CURVE SHEET

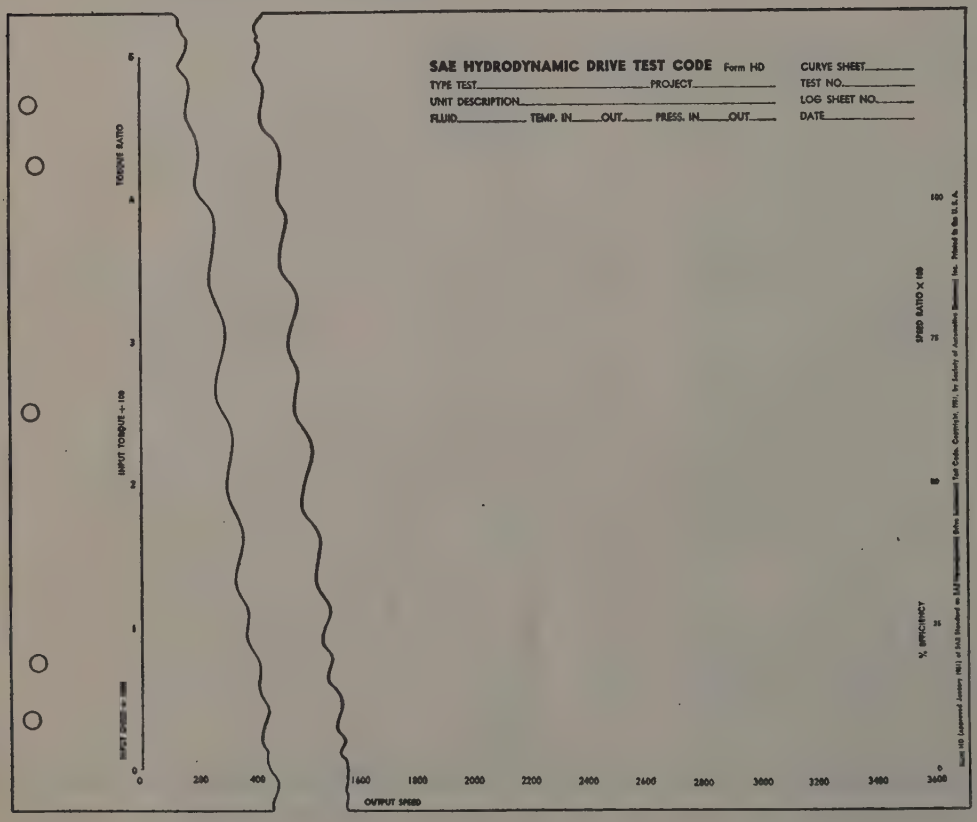


FIG. 5—FORM HD, CURVE SHEET

Brake Linings, Rivets, and Bolts

SAE Standard

Report of Brake Technical Committee approved February 1948 and last revised November 1950.

This standard covers riveted, bolted, and bonded brake linings. Bonded linings shall not be drilled for rivets or bolts.

Brake Measurement—The outside diameter of the brake, that is, the outside diameter of the lining and shoe assembly mounted on the backing plate, is considered the measure of brake size and is designated in even inches on the inch as basic. A single or basic thickness of lining is used in connection with this basic brake diameter.

PART I

This part covers sizes and drilling patterns for passenger-car and light-commercial-vehicle types of riveted brake linings for brake sizes 8 to 12 in. inclusive.

Brake-Lining Measurements

1. Basic outside brake diameters are in even inches on the inch.

2. Basic thickness of lining is 3/16 in., deviations to be in increments of 1/16 in. with consequent changes in outside brake diameters.

3. Widths of lining range from 1½ in. upwards in increments of ¼ in.

4. Basic lengths of lining are 93 deg or 120 deg or both, arcwise, deviations to be in increments of 13 deg. 30 min.

5. Rivet-hole spacing is 6, 27, 27, 27, and 6 deg arcwise for 93-deg lengths; and 6, 27, 27, 27, 27, and 6 deg for 120-deg lengths. Intermediate rivet holes are to be spaced arcwise halfway between or at 13 deg, 30 min. Centers of rivet holes spaced across the lining are to be 3/8 in. from the edge of the lining for widths up to 2½ in. inclusive, and ½ in. from the edge of the lining for widths greater than 2½ in.

6. Brake-lining manufacturers' tolerances are as follows:

Lengths	+1/8, −0
Widths	+0, −1/32
Thickness, production[1]	Nom, +0.030, +0.010
Thickness, service[2]	Nom, +0.000, −0.020

It is recommended that drill diameters for rivet holes be not more than 1/64 in. greater than rivet-shank diameters and that countersink diameters be not more than 1/32 in. greater than rivet-head diameters.

PART II

This part covers sizes and drilling patterns for truck and bus riveted and bolted brake linings for brake sizes 13 in. and larger.

There are two standard brake linings for truck- and bus-type brakes, one for brakes using lining less than ½ in. in thickness and the other for brakes using lining ½ in. and over. Pieces of lining less than ½ in. in thickness are designated as *segments*, and those ½ in. and over as *blocks*.

Brake-Segment Measurements

1. Basic outside brake diameters are in even inches on the inch.

2. Basic thickness of segments is ¼ in. for 13- to 15-in. brakes inclusive, 3/16 in. for 16-in. brakes and larger. Deviations shall be in increments of 1/16 in. with consequent changes in outside brake diameters.

3. Widths of segments range from 1¾ in. upwards for 13- and 14-in. brakes; 2 in. upwards for 15-in. brakes; and 2¼ in. upwards for 16-in. brakes and larger, in increments of ¼ in.

4. Basic lengths of segments are 98 deg or 120 deg or both, arcwise deviations to be in increments of 11 deg.

5. Rivet-hole spacing is 5, 22, 22, 22, 22, 5 deg arcwise for 98-deg lengths and 5, 22, 22, 22, 22, 22, 5 deg for 120-deg lengths; intermediate rivet holes arcwise to be spaced halfway between or at 11 deg. Center of rivet holes spaced across the segment are 3/8 in. from edge of segment for widths up to 2 in. inclusive, ½ in. from edge of segment for widths greater than 2 in. Where additional rivets nearer the centerline of the segment are desired, centers of rivet holes shall be spaced 2 in. apart horizontally or 1 in. from each side of centerline, and arcwise halfway between standard rivet holes or at 11 deg. It is considered to be within this Standard to omit any rivet holes.

5. Brake-lining manufacturers' tolerances for segments are as follows:

Lengths	+1/8, −0
Widths	+0, −1/32
Thickness, production[3]	Nom, +0.030, +0.010
Thickness, service[4]	Nom, +0.000, −0.020

It is recommended that drill diameters for rivet holes be not more than 1/64 in. greater than rivet-shank diameters and that countersink diameters be not more than 1/32 in. greater than rivet-head diameters.

Brake-Block Measurements

1. The basic outside brake diameters shall be in even inches on the inch, starting with 13 in. Optional deviations shall be in increments of ½ in.

2. Basic thickness of blocks is ¾ in., deviations to be in increments of ⅛ in. with consequent changes in shoe radii.

The block standard differs from the segment standard in that it alters the shoe radii rather than the drum diameter to compensate for changes in thickness. It was so set up because in the larger brake sizes the diameter of the drum is limited by the size of the wheel and in many cases cannot feasibly be made larger.

3. Width of blocks is 3 in. and upwards in increments of ½ in

4. Basic length of blocks is 58 deg.

5a. Hole spacing for bolts is 7, 44, 7 deg arcwise; intermediate bolt holes shall be spaced halfway between or at 22 deg. Center of bolt holes spaced across the block shall be one half the width of the block apart in the case of blocks of full inch widths,

TABLE 1—*Horizontal Bolt-Hole Spacing*

WIDTH OF BLOCK	HORIZONTAL BOLT-HOLE SPACING	WIDTH OF BLOCK	HORIZONTAL BOLT-HOLE SPACING
3	1½	6	3
3½	2	6½	3½
4	2	7	3½
4½	2½	7½	4
5	2½	8	4
5½	3		

[1] Before finishing for final assembly as supplied by brake-lining manufacturers for original equipment.
[2] As supplied by brake-lining manufacturers for assembly without additional finishing.
[3] Before finishing for final assembly as supplied by brake-lining manufacturers for original equipment.
[4] As supplied by brake-lining manufacturers for assembly without additional finishing.

TABLE 2—*Dimensions of Brass Tubular Rivets for Brake Linings*

RIVET SIZE NO.	SHANK DIAMETER, *S*			HEAD DIAMETER, *H*			HEAD THICKNESS			DRILL		LENGTH, *L*
	Nom	Max	Min	Nom	Max	Min	*T*	T_1	T_2	Size, *D*	Depth, *E*	
4	9/64	0.148	0.140	19/64	0.301	0.291	0.034 ± 0.003	0.005	0.020	No. 39 (0.0995)	1/8	As specified in increments of 1/16 in.
5	9/64	0.148	0.140	23/64	0.364	0.354	0.045 ± 0.003	0.005	0.028	No. 39 (0.0995)	5/32[a]	
7	3/16	0.190	0.180	23/64	0.364	0.354	0.046 ± 0.003	0.009	0.023	No. 29 (0.136)	7/32[b]	
8	3/16	0.190	0.180	15/32	0.478	0.458	0.065 ± 0.004	0.012	0.037	No. 29 (0.136)	7/32	
10	1/4	0.250	0.240	15/32	0.478	0.458	0.058 ± 0.004	0.012	0.030	No. 16 (0.177)	9/32	

[a] 3/16-in. length will have 1/8-in. drill depth.
[b] 1/16- and 5/16-in. lengths to have 5/32-in. drill depths.

and one half the width of the next full inch block apart in the case of blocks of intermediate 1/2-in. widths as shown in Table 1. Any deviation of this spacing shall be in increments of 1/2 in.

5b. Hole spacing for rivets is 7, 22, 22, 7 deg, with intermediate holes spaced halfway or at 11 deg. Center of rivet holes spaced across the block shall be 3/4 in. from edge of block. In the case of 6-in. blocks or wider where additional rivets nearer the centerline of the blocks are desired, centers of rivet holes shall be spaced 2 3/4 in. apart horizontally or 1 3/8 in. from each side of centerline of block. It is considered to be within this Standard to omit any rivet holes.

6. Brake-lining manufacturers' tolerances for blocks are as follows:

Lengths	±1/8
Widths	±1/32
Thickness, production[5]	Nom, +0.030, +0.010
Thickness, service[6]	Nom, −0.015, −0.030

PART III

This part applies to brass tubular rivets for brake linings and bolts for brake blocks.

Brass Tubular Rivets for Brake Linings—Table 2 and Fig. 1 give dimensions for brass tubular rivets used for brake linings.

The eccentricity between rivet head and shank must be no greater than 0.010 in., and the eccentricity between the hole in the shank and the shank must be no greater than 0.010 in.

Bolts for Brake Blocks—The standard bolt for blocks shall be a brass, slotted-flathead capscrew with a 3/8-in. diameter body, a 3/4-in. diameter head having an inclusive angle of countersink of 82 deg conforming to the SAE Standard for Slotted- and Recessed-Head Screws.

It is recommended that drill and countersink diameters for bolt holes be 25/64 in. and 49/64 in. respectively, with the bottom of the countersink within 3/32 in. ±0.010 of the shoe side of blocks.

The general bolt dimensions given with Fig. 2 are recommended. For other dimensions, refer to Table 2 of the SAE Standard for Slotted- and Recessed-Head Screws.

[5] Before finishing for final assembly as supplied by brake-lining manufacturers for original equipment.
[6] As supplied by brake-lining manufacturers for assembly without additional finishing.

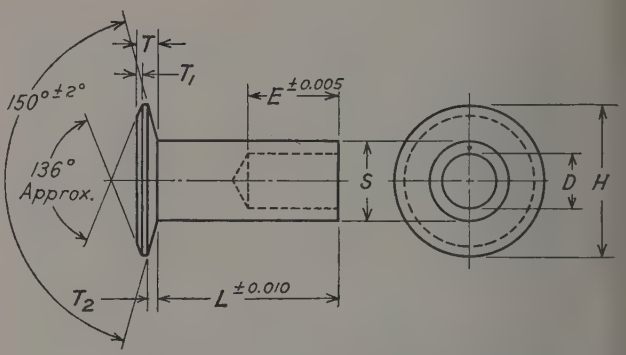


FIG. 1—BRASS TUBULAR RIVET FOR BRAKE LINING

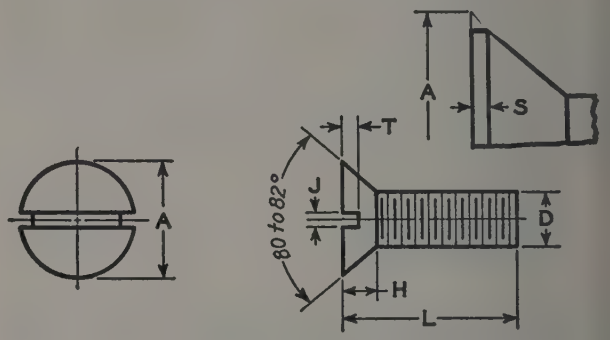


FIG. 2—SLOTTED-FLATHEAD CAPSCREW FOR BRAKE BLOCKS
A = 3/4-in. diameter
D = 3/8"—24 NF
L = 1 3/8 in.

Body Moldings and Fasteners

SAE Recommended Practice

Report of Passenger-Car Body Engineering Technical Committee approved June 1948.

Molding fasteners may be divided into four general types defined as follows:

Snap-On Type—The fastener is secured to the panel first, then the molding is snapped over the fastener.

Slide-In Type—The fastener is assembled into the molding by sliding it into place before it is snapped to the panel.

Turn-In Type—The fastener is secured in the molding by turning the fastener into the molding before it is snapped to the panel.

Bolt and Nut—The molding is secured to the panel by means of a bolt and nut.

Tolerances and Limitations—For the following dimensions, see Fig. 1.

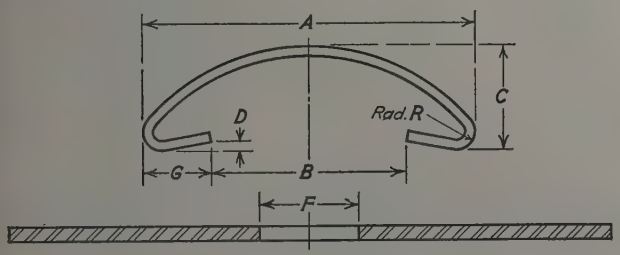


FIG. 1—BODY MOLDING

Dimension A—A tolerance of ±0.010 in. is recommended for straight moldings. It is deemed inadvisable to designate tolerances on bent moldings because the reduction in width fluctuates considerably with variation in the bending radii.

It is recommended that molding widths vary in increments of 1/32 in. for moldings from 3/16 to 1/2 in. wide inclusive, and in increments of 1/16 in. for moldings from 1/2 to 1 in. wide inclusive. For moldings wider than 1 in., increments of 1/8 in. are recommended.

Dimension B—A tolerance of +0.000, −0.020 in. is recommended when *snap-on* type fasteners are used. When any fastener other than a snap-on type is used, a tolerance of +0.020, −0.000 in. is recommended for moldings up to 1/2 in. wide inclusive. For moldings wider than 1/2 in., a tolerance of ±0.020 in. is recommended.

Dimension C—When metal 0.020 in. thick or lighter is specified for *oval shapes*, dimension *C* should be held to 5/32 in. minimum. When *flat-top* shapes are used, dimension *C* should be held to a minimum of 1/8 in.

Dimension D—Dimension *D* should be specified as 1/64 in. from the surface of the metal to which the molding is to be fastened. A tolerance of +0.010, −0.005 in. is recommended.

Dimension G—When metal 0.018 to 0.020 in. thick is used, dimension *G* should be held, in general, within the range of 0.100 to 0.160 in., with a 0.190 in. maximum for *snap-on* fasteners. When *turn-in* or *slide-in* type fasteners are used, dimension *G* should be 0.100 in minimum.

Radius R—Regardless of shape of molding, *R* (outside of metal) should be specified not less than twice the metal thickness.

Molding Thickness and Method for Dimensioning—It is recommended that when snap-on type fasteners are used, metal thickness be held within the range of 0.018 to 0.025 in.

Method for Dimensioning Molding—It is recommended that moldings be dimensioned to outside of metal in all cases. Outside conditions are more important to the stylist than inside contours.

Moldings and Fastener Drawings—It is recommended that molding and fasteners be shown on the detail drawing 10 times size for proper control of dimensions by shadow-graph.

Avoid locating fasteners on sharp bends because of unavoidable reduction in molding section width at these points.

Automotive Glazing

SAE Standard

Report of Passenger-Car Body Engineering Technical Committee approved July 1950.

Glass Sizes—There are no standard sizes in automotive glass. Maximum sizes must be determined between the automotive engineering department and the glass manufacturer. Maximum sizes for bent or curved glass are less than those for flat glass and depend upon the degree of bending and capacity of bending equipment.

Note: Overall width and length dimensions of block sizes are held to full inch increments.

The following types of glass (flat or bent) are covered: laminated safety plate glass; laminated safety sheet glass; heat-treated safety plate glass; polished wire glass.

Commercial Tolerances

1. *Thickness*—Flat or bent safety glass.

Type of Glass	*Thickness Range, In.*
Laminated safety plate	7/32–9/32
Laminated safety thin plate	9/64–13/64
Laminated safety sheet (SS and DS)[1]	13/64–17/64
Laminated safety sheet (SS and SS)[1]	3/16–1/4
Laminated safety sheet (DS and DS)[1]	7/32–19/64
Laminated safety thin sheet	1/8–11/64
Heat-treated safety plate	7/32–9/32
Polished wire glass	7/32–9/32

2. *Flatness*—Flat laminated safety plate glass, flat laminated safety sheet glass, flat heat-treated safety plate glass, and polished wire glass shall have 1/32 in. maximum total bow per each lineal ft. Reverse curves or crooked glass not acceptable.

3. *Curvature*

(a) Bent laminated safety plate glass and bent heat-treated safety plate glass shall have 1/8-in. departure from curve of periphery-type checking fixture, such deviation not to vary more than 1/16 in. per lineal ft.

Note: Curvature tolerances should be checked with the glass manufacturer as extreme radii or sharp bends may require different tolerances.

(b) Cross-sectional sag tolerances must be checked with the glass manufacturer before specifying on drawing.

4. *Overall Size*—Tolerance for flat laminated safety plate glass, flat laminated safety sheet glass, and polished wire glass is ± 1/32 in.; flat heat-treated safety plate glass, ± 1/16 in. for width and length up to and including 1/4-in. nominal thickness, unless otherwise specified.

Tolerances for bent laminated safety plate glass, bent heat-treated safety plate glass, and bent polished wire glass are affected by pattern and degree of curvature and should be checked with the glass manufacturer.

[1] SS signifies single strength; DS signifies double strength.

Edges and Definitions

Edge No. 1—Crown Edge, Satin Finish (Fig. 1a) indicates a radius fine grind along the edge and leaving no sharp edges. Radius need not be a true radius.

Edge No. 2—Crown Edge, Semi-Satin Finish (Fig. 1b) indicates a modification of Edge No. 1 where the finish is not so fine, and occasional flats and wheel skips are permissible in center area only.

Edge No. 3—Semi-Crown Edge, Semi-Satin Finish (Fig. 1c) indicates a modification of Edge No. 2 where the central part of the edge need not be touched with the edging wheel.

Edge No. 4—Seamed Edge (Fig. 1d) indicates that the original cut edge of the glass is to be ground off to an angle of approximately 45 deg. The width of the seam should be approximately 1/16 in. measured across the flat of the seam. A seamed edge is the minimum type of edge acceptable for heat-treated safety plate glass.

Edge No. 5—Clean-Cut Edge (Fig. 1e) indicates that the glass part has no further work done upon the original cut edges and allows no flare exceeding 1/64 in. This type edge not acceptable for heat-treated safety plate glass.

For various applications and locations of the above edgings, see Figs. 2 through 8.

Overlap—An overlap of 1/32 in. of one sheet over the other on all edges, except crown-edge finishes No. 1 and 2, shall be permissible, unless otherwise specified, provided the overall dimension is within tolerance.

Tong Marks—Tong marks must be located 5/16 in. maximum from edge of glass.

Mold Marks—Mold marks to be held to 1/4 in. maximum from edge of glass, unless otherwise specified.

Markings—Markings are to be in accordance with current American Standard Safety Code for Safety Glazing Materials, ASA Z26.1.

Any other special identifying marks required must be specified and located on the drawing and must be apart from glass manufacturer's distinctive trade mark, also other markings required by law, ordinance, or regulation.

Location of markings must be visible after installation for identification.

(*Figs. 1–8 begin on next page.*)

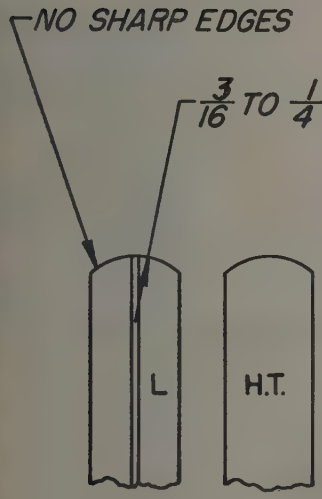


FIG. 1a—EDGE NO. 1, CROWN EDGE, SATIN FINISH FOR ALL EXPOSED EDGES

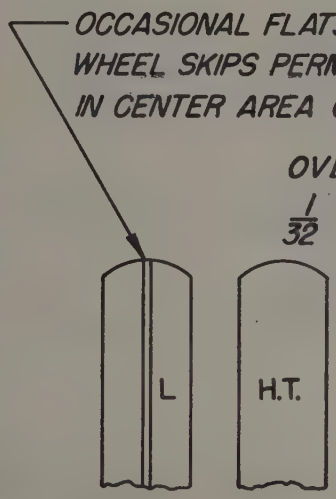


FIG. 1b—EDGE NO. 2, CROWN EDGE, SEMI-SATIN FINISH FOR UNEXPOSED EDGES SLIDING IN CHANNELS

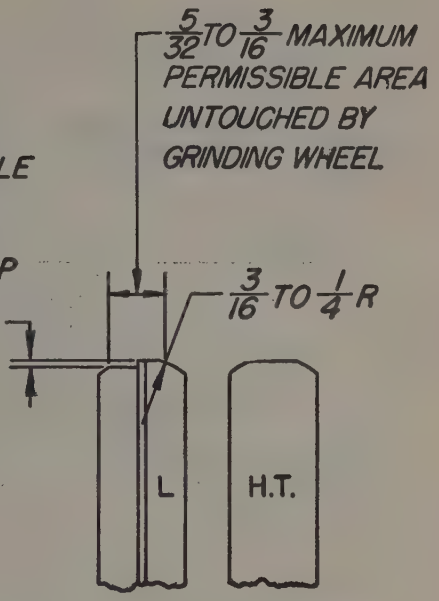


FIG. 1c—EDGE NO. 3, SEMI-CROWN EDGE, SEMI-SATIN FINISH FOR EDGES ENCLOSED IN FIXED CHANNELS

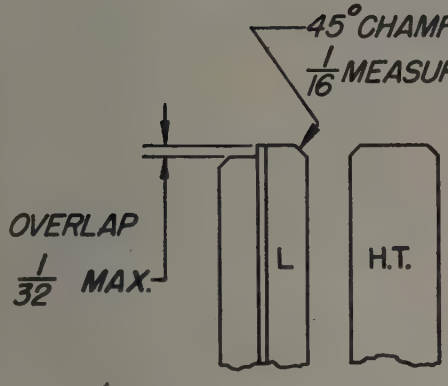


FIG. 1d—EDGE NO. 4, SEAMED EDGE FOR EDGES ENCLOSED IN FIXED CHANNELS

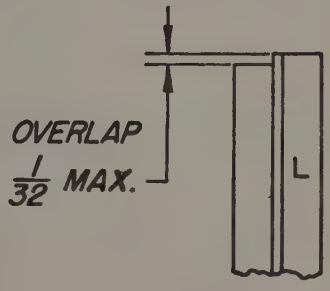


FIG. 1e—EDGE NO. 5, CLEAN-CUT EDGE FOR EDGES ENCLOSED IN FIXED CHANNELS

Notes for Figs. 1a through 1e

Note 1—L = laminated glass; HT = heat-treated glass

Note 2—Glass manufacturer is not required to furnish a true radius on any edge where a radius is specified

(*Continued on next page.*)

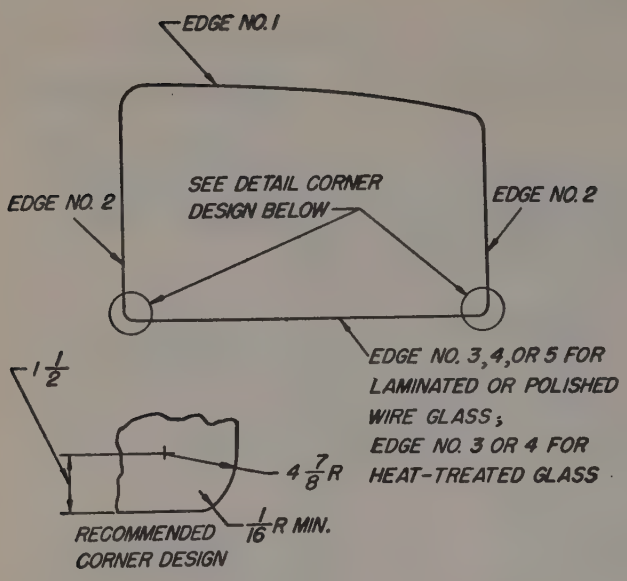

EDGE NO. 1
EDGE NO. 2
SEE DETAIL CORNER DESIGN BELOW
EDGE NO. 2
EDGE NO. 3, 4, OR 5 FOR LAMINATED OR POLISHED WIRE GLASS; EDGE NO. 3 OR 4 FOR HEAT-TREATED GLASS
1 1/2
4 7/8 R
1/16 R MIN.
RECOMMENDED CORNER DESIGN

FIG. 2—VERTICALLY SLIDING DOOR OR QUARTER WINDOW WITH METAL CHANNEL ON ONE SIDE ONLY

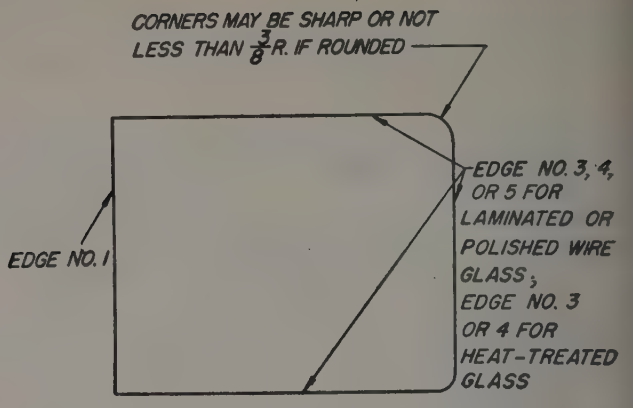

CORNERS MAY BE SHARP OR NOT LESS THAN 3/8 R. IF ROUNDED
EDGE NO. 3, 4, OR 5 FOR LAMINATED OR POLISHED WIRE GLASS; EDGE NO. 3 OR 4 FOR HEAT-TREATED GLASS
EDGE NO. 1

FIG. 3—SLIDING WINDOW WITH METAL CHANNEL ON THREE SIDES

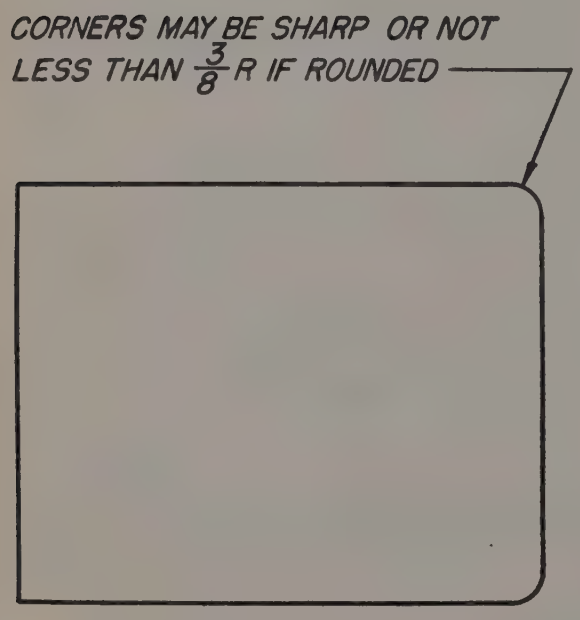


FIG. 4—SLIDING WINDOW WITH METAL CHANNEL ON FOUR SIDES—EDGE NO. 3, 4, OR 5 FOR LAMINATED OR POLISHED WIRE GLASS ALL AROUND; EDGE NO. 3 OR 4 FOR HEAT-TREATED GLASS ALL AROUND

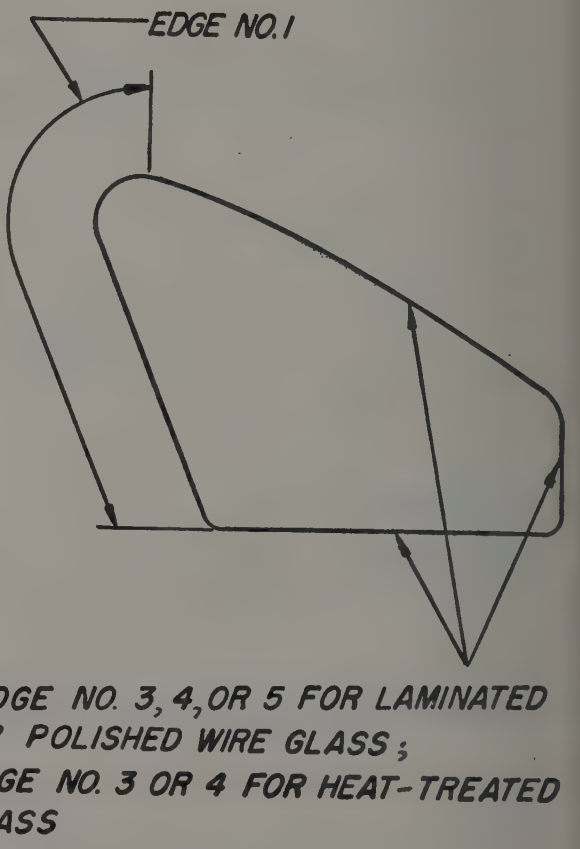


FIG. 5—HORIZONTALLY SLIDING WINDOW, ONE EXPOSED EDGE

(*Continued on next page.*)

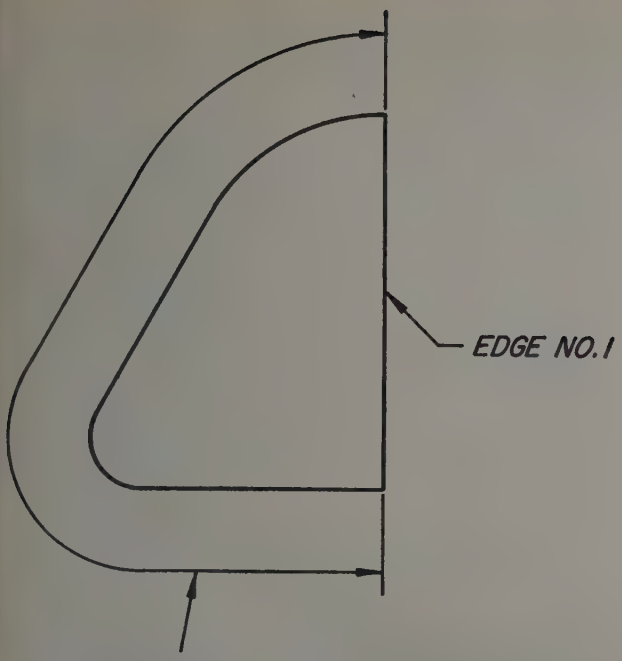


FIG. 6—SWING VENTILATOR GLASS, ONE EXPOSED EDGE

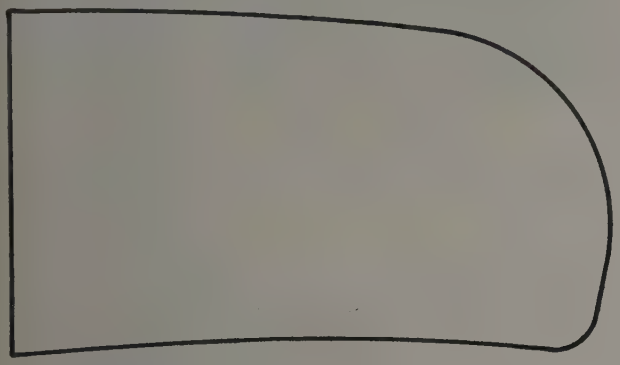


FIG. 7—WINDSHIELD GLASS, NO EXPOSED EDGES—EDGE NO. 3, OR 4, OR 5 ALL AROUND

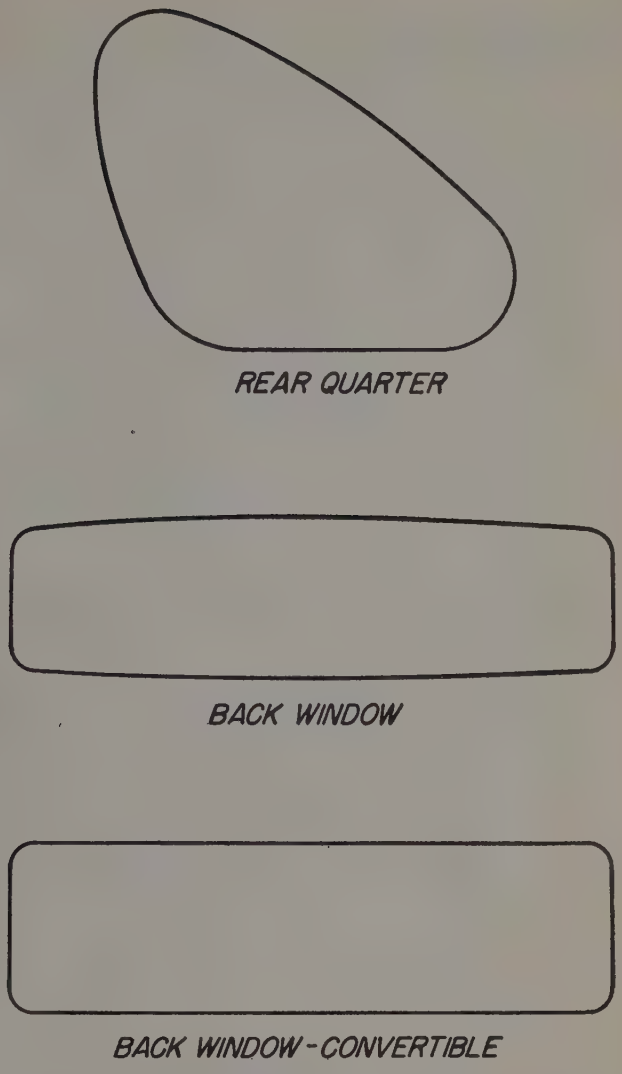


FIG. 8—STATIONARY WINDOWS, ALL TYPES—EDGE NO. 3, 4, OR 5 FOR LAMINATED OR POLISHED WIRE GLASS ALL AROUND; EDGE NO. 3 OR 4 FOR HEAT-TREATED GLASS ALL AROUND

Glazing Glass

SAE Recommended Practice

Report of Passenger-Car Body Division approved March 1923 and last revised by Passenger Car Division January 1937.

[*With the development of what is commonly termed "safety glass" the diversity in claims for its manufacture and use and its requirement by Federal and State motor-vehicle laws or regulations led to the organization of a Sectional Committee in June 1934 under American Standards Association procedure to formulate a standard safety code for all safety glass. The first code developed under this procedure related to land motor vehicles only, and a Safety Glass Advisory Committee of the Society was appointed under the Passenger Car Division which cooperated with the Sectional Committee in developing the original American Tentative Standard Z26.1—1935. This was subsequently revised (Z26.1—1938) with reference to trade marking of the glass. As the American Standard provides only for standard tests and marking, this SAE Recommended Practice is intended primarily as a guide to the proper thickness in the selection of glass for use in land motor vehicles.*]

All glazing glass used in motor vehicles normally operating on land should comply with the requirements of American Standard Z26.1—1938 (and Supplement Z26.1a—1948) or subsequent revisions.

Definition[1]—The term *safety glass* shall be construed as meaning glass so treated or combined with other materials as to reduce, in comparison with ordinary sheet glass or plate glass, the likelihood of injury to persons by objects from exterior sources or by glass when the glass is cracked or broken.

General[1]—As the definition indicates, safety glass in comparison with ordinary glass is intended to reduce the likelihood of injury. Therefore terms such as nonbreakable, nonshatterable, nonscatterable, nonsplinterable, and others should not be interpreted by the driving public as meaning that complete protection is afforded to the occupants of the vehicle under all conditions.

Under some accident conditions, one type of safety glass may be superior while under other accident conditions another type of safety glass may be superior. Since accident conditions are not standardized, no one type of safety glass can be shown to possess the maximum degree of safety under all conditions.

Thickness of Glass—Automobiles, including trucks and buses, are normally equipped with safety glass that is from $\frac{7}{32}$ in. to $\frac{9}{32}$ in. thick.

Glass mounted in flexible material (such as curtains) on motor vehicles is normally laminated safety glass that is $\frac{5}{32}$ in. thick minimum.

Armored cars are normally equipped with bullet-resisting glass that is $1\frac{1}{8}$ in. or more in thickness.

Note: The following specifications or revisions thereof are noted as references to more complete specifications for glass in vehicles other than those normally operating on land highways.

U. S. Army Specification 81-11-B—Chief, Materiel Div., Air Corps, Dayton, O., or U. S. Army Air Corps, Munitions Building, Washington, D. C.

U. S. Navy Specification 49G3 (aircraft) and Specification 12G5 (marine vessels)—Bureau of Supplies and Accounts, Munitions Building, Washington, D. C.

U. S. Federal Specification DDG-451 (general)—Sup't. of Documents, U. S. Gov't. Printing Office, Washington, D. C.

The above specifications may also be obtained from the Procurement Div., U. S. Treasury, Federal Warehouse Extension, Washington, D. C.

[1] From American Standard Z26.1—1938 (and Supplement Z26.1a—1948).

Window-Glass Runways and Channels

SAE Recommended Practice

Report of Passenger-Car Body Engineering Technical Committee approved May 1950.

Definition and Purpose—The term *glass-run channel* has been adopted and is intended to refer to various U-shaped channels of any construction and material which are inserted in the body or body member structure and in which window glass is semi-rigidly retained laterally but free to slide in plane of glass, and which at the same time offer a degree of sealing between glass and channel.

The term *glass-run weatherstrip* has been adopted and is intended to refer to devices having construction and materials similar to glass-run channels but which do not provide restraint to glass movement in more than one direction, nor seal the glass on more than one side or one edge. Several glass-run weatherstrips used together may perform the same function as the glass-run channel.

This standard is intended for use as a guide in selecting type and basic dimensions of glass-run channels and glass-run weatherstrips.

It is not the purpose of this standard to establish structural design or materials to be used in the manufacture of these glass-run channels and weatherstrips.

Since it is not within the scope of this standard to include all the sizes, types, and constructions which have been manufactured, only the shapes and basic dimensions of preferred designs generally available as of 1948 are included.

Glass-Run Channel—Glass-run channels are constructed on a metallic (or other structural material) channel which may be designed so that they can be bent to fit the glass profile. The structural channel is lined with a suitable material, such as felt

or pile, by means of a suitable binder and whatever intermediate medium might be required or necessary to the application.

The lining thickness, material, and construction as well as clearance between glass and lining depend upon many variables peculiar to the application.

Glass-run channels are used generally between the glass and window structure where the glass must be free to slide in the glass plane and be reasonably restrained from moving or vibrating at right angles to this plane.

The glass-run channel, besides functioning as a glass guide, performs the function of a weather seal between the glass and window opening. This requires a minimum clearance (frequently negative) between the glass and glass-run-channel lining. The glass-run channel must also fit tightly in the window structure to prevent excessive leakage or movement between the channel and the recess in which it is held.

Often felt or other suitable material is provided in the base of the channel to guide the edge of the glass.

The designs of glass-run channels shown in Figs. 1 and 2 represent the commonly used glass-run channel and portray in the one case a channel with a fabric finish on the exposed edges, and in the second case a metallic bead. The sizes shown in Table 1 are to include a wide range of applications from the smaller sizes used in a "division bar" to a large size used in trucks to accommodate a glass with a steel frame around it.

Special forms of glass-run channels, such as illustrated by Figs. 3–5, are standard designs available for use where two panes of glass must slide, generally horizontally as in station-wagon construction, past each other. Fig. 3 is applicable where both panes must slide, while the sections shown by Figs. 4 and 5 are for use where one pane slides and a filler or finish is required for the open end of the groove provided for the other pane.

Glass-Run Weatherstrip—Glass-run weatherstrip is constructed on a metallic (or other structural material) body, generally flat, which may be designed so that it can be bent to fit the contour of the window-opening structure. The body has a felt, pile, or other suitable material, covering one side or part of one side, attached by means of a suitable binder and whatever intermediate medium might be required or necessary to the application. The height or thickness of this felt or pile material is to be determined by the designer so that proper fit is made to produce the seal or degree of rigidity required. Table 2 gives dimensions of glass-run weatherstrips.

The shapes of the cross-section of the most generally used glass-run weatherstrips are shown in Figs. 6–10. Figs. 6 and 7 illustrate the flat, plain, and beaded types which are supplied in strip form. The metal bead shown in Fig. 7 may be for structural or decorative purposes.

The sections shown in Figs. 6, 7, and 9 are generally attached by mechanical means to the metal around the glass opening to provide lateral restraint to glass movement as well as weather sealing. With this construction, the section shown in conjunction with Fig. 9 is used to fill the window structure at the glass edge. The combined use of sections from Figs. 6, 7, and 9 result in a built-up channel which is frequently used as a substitute for or in place of, a glass-run channel. The choice of use depends

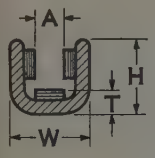


Fig. 1—Single Plain Channel

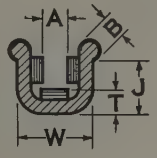


Fig. 2—Single Beaded Channel

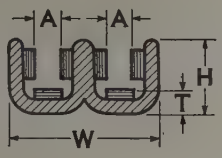


Fig. 3—Double Plain Channel

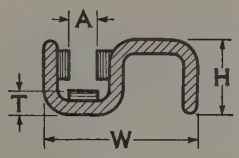


Fig. 4—Plain Channel

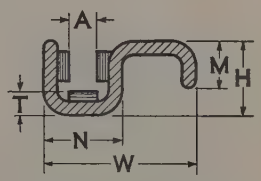


Fig. 5—Plain Channel

TABLE 1—*Glass-Run Channel Dimensions*[a] *in Inches*

TYPE	$W \pm 1/64$	$H \pm 1/32$	$J \pm 1/64$	$T \pm 1/64$	$B \pm 1/64$	$M \pm 1/32$	$N \pm 1/64$
Single Plain, Fig. 1	1/2	3/8	—	5/32	—	—	—
	1/2	1/2	—	5/32	—	—	—
	5/8	1/2	—	5/32	—	—	—
	5/8	9/16	—	5/32	—	—	—
	27/32	5/8	—	3/16	—	—	—
Single Beaded, Fig. 2	1/2	—	9/32	7/64	7/64	—	—
	1/2	—	13/32	7/64	7/64	—	—
	5/8	—	15/32	5/32	7/64	—	—
Double Plain, Fig. 3	15/64	1/2	—	5/32	—	—	—
	17/64	1/2	—	5/32	—	—	—
Plain, Fig. 4	15/64	1/2	—	5/32	—	—	—
Plain, Fig. 5	15/64	1/2	—	5/32	—	7/32	5/8

[a] Dimension *A* depends on design and application.

generally upon consideration determined by the construction details of the window-opening structure.

The section illustrated by Fig. 8 is primarily a weather seal used between two pieces of glass which slide one past the other. The channel construction is of such dimensions that it will, when forced on the edge of the glass, be retained there by friction between the material and the glass. The felt or pile face contacts the second glass forming a weatherseal.

A section shown by Fig. 10 is used to fill the corner and seal an edge and one face of a glass which pivots to open such as the "no-draft ventilating windows." It is retained by a metal lip formed over the thin edge of the weatherstrip and rivets recessed in the other leg.

There are numerous other special-application glass-run weatherstrips which do not have sufficiently general application to be included in this standard.

Glass-Run Channel and Glass-Run Weatherstrip Dimensions—In both Tables 1 and 2, the extreme-left column designates the general type with reference to the corresponding figure and the following columns list the preferred basic dimensions.

The tolerances shown are those recommended by the manufacturers and are the minimum practical variations which can be produced commercially for materials and structures of this type. Except where necessity demands smaller tolerances, those shown should be adhered to for general practice.

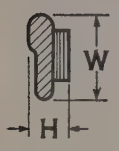


FIG. 6—PLAIN WEATHERSTRIP

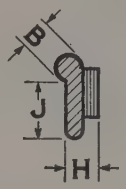


FIG. 7—BEADED WEATHERSTRIP

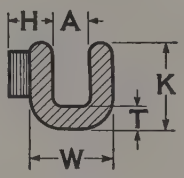


FIG. 8—CHANNEL WEATHERSTRIP

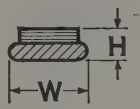


FIG. 9—BOTTOM WEATHERSTRIP

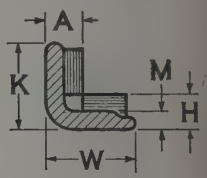


FIG. 10—DIVISION-BAR WEATHERSTRIP

TABLE 2—*Glass-Run Weatherstrip Dimensions in Inches*

TYPE	$W \pm 1/64$	$H \pm 1/64$	$J \pm 1/64$	$T \pm 1/64$	$K \pm 1/64$	$A \pm 1/64$	$B \pm 1/64$	$M \pm 1/64$
Plain, Fig. 6	3/8	—[a]	—	—	—	—	—	—
	7/16	—[a]	—	—	—	—	—	—
	1/2	—[a]	—	—	—	—	—	—
	9/16	—[a]	—	—	—	—	—	—
Beaded, Fig. 7	—	—[a]	9/32	—	—	—	7/64	—
	—	—[a]	11/32	—	—	—	7/64	—
	—	—[a]	13/32	—	—	—	7/64	—
	—	—[a]	15/32	—	—	—	7/64	—
Channel, Fig. 8	15/32	—[a]	—	7/64	29/64	—[a]	—	—
Bottom Strip, Fig. 9	5/8	5/32	—	—	—	—	—	—
	13/16	7/32	—	—	—	—	—	—
Division Bar, Fig. 10	7/16	7/32	—	—	13/32	7/32	—	1/16

[a] Depends on design and application.

Window-Regulator-Handle and Door-Handle Mountings

SAE Standard

Report of Passenger-Car Body Engineering Technical Committee approved March 1950.

[Figs. 1, 2, and 3 pertain to serrated mountings. Figs. 4 and 5 pertain to square mountings. Mountings in Figs. 4 and 5 differ in that Fig. 4 is for the cross-pin method of mounting and Fig. 5 for mounting by means of a screw in the face.]

Serrated Type

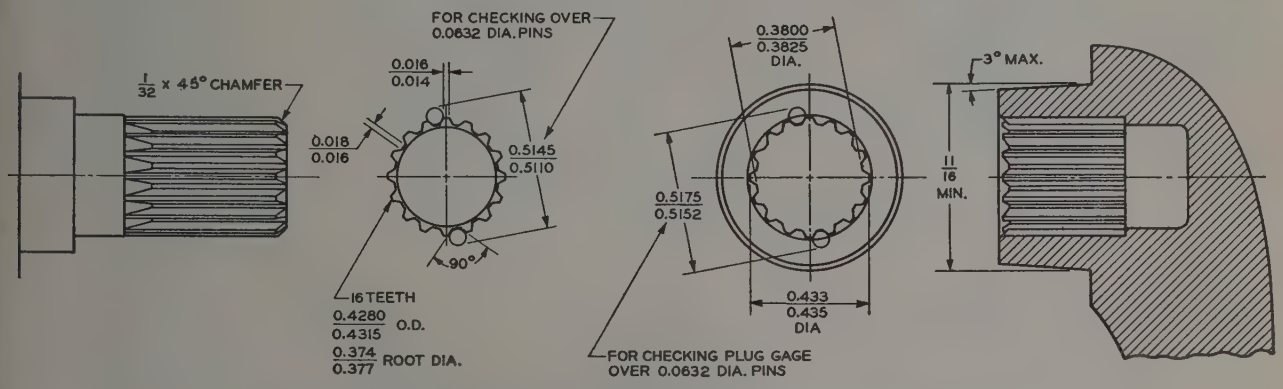


FIG. 1—SERRATED TYPE OF WINDOW-REGULATOR-HANDLE AND DOOR-HANDLE MOUNTINGS
Methods of mounting: snap ring, screw in face, or set screw

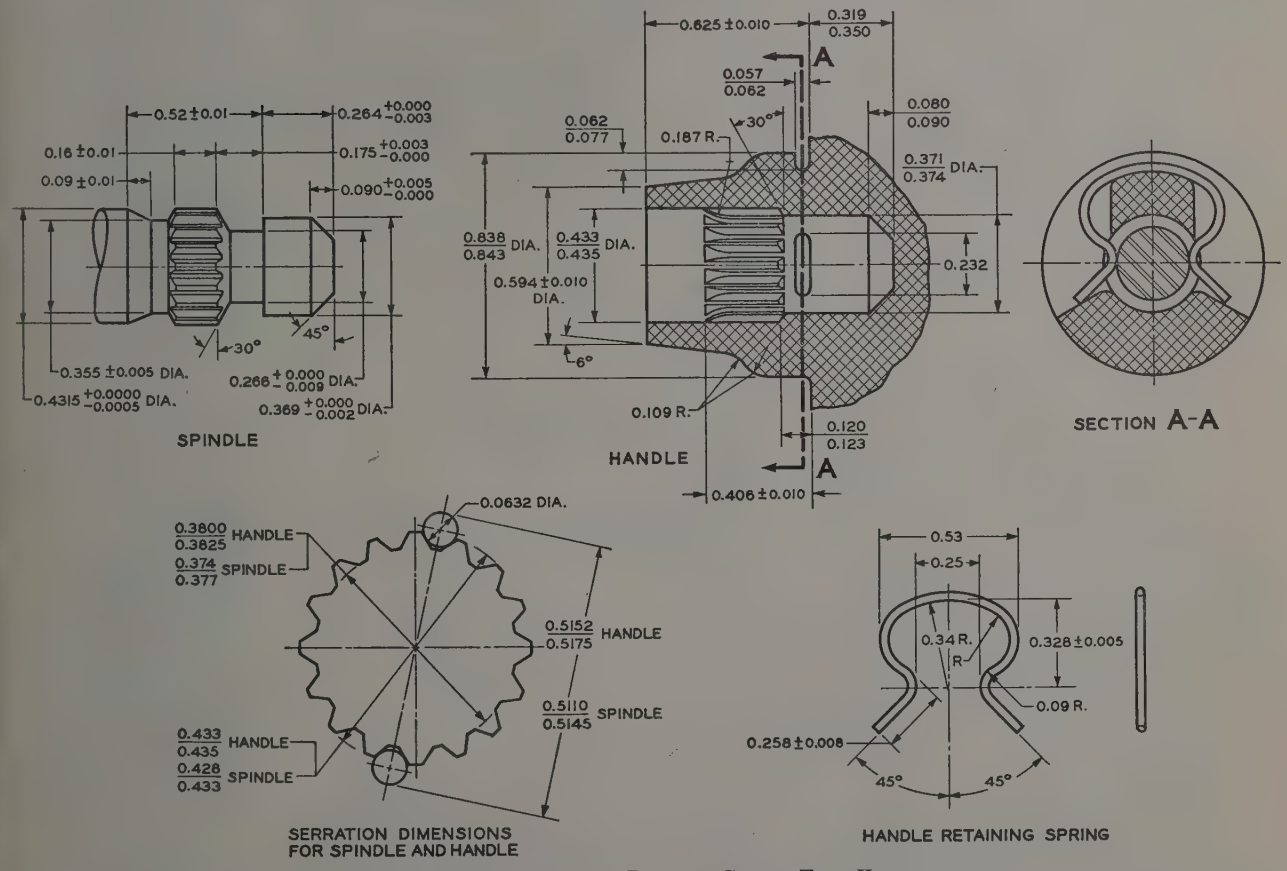


FIG. 2—SERRATION DATA FOR REGULAR-CLUTCH-TYPE HARDWARE

(Continued on next page.)

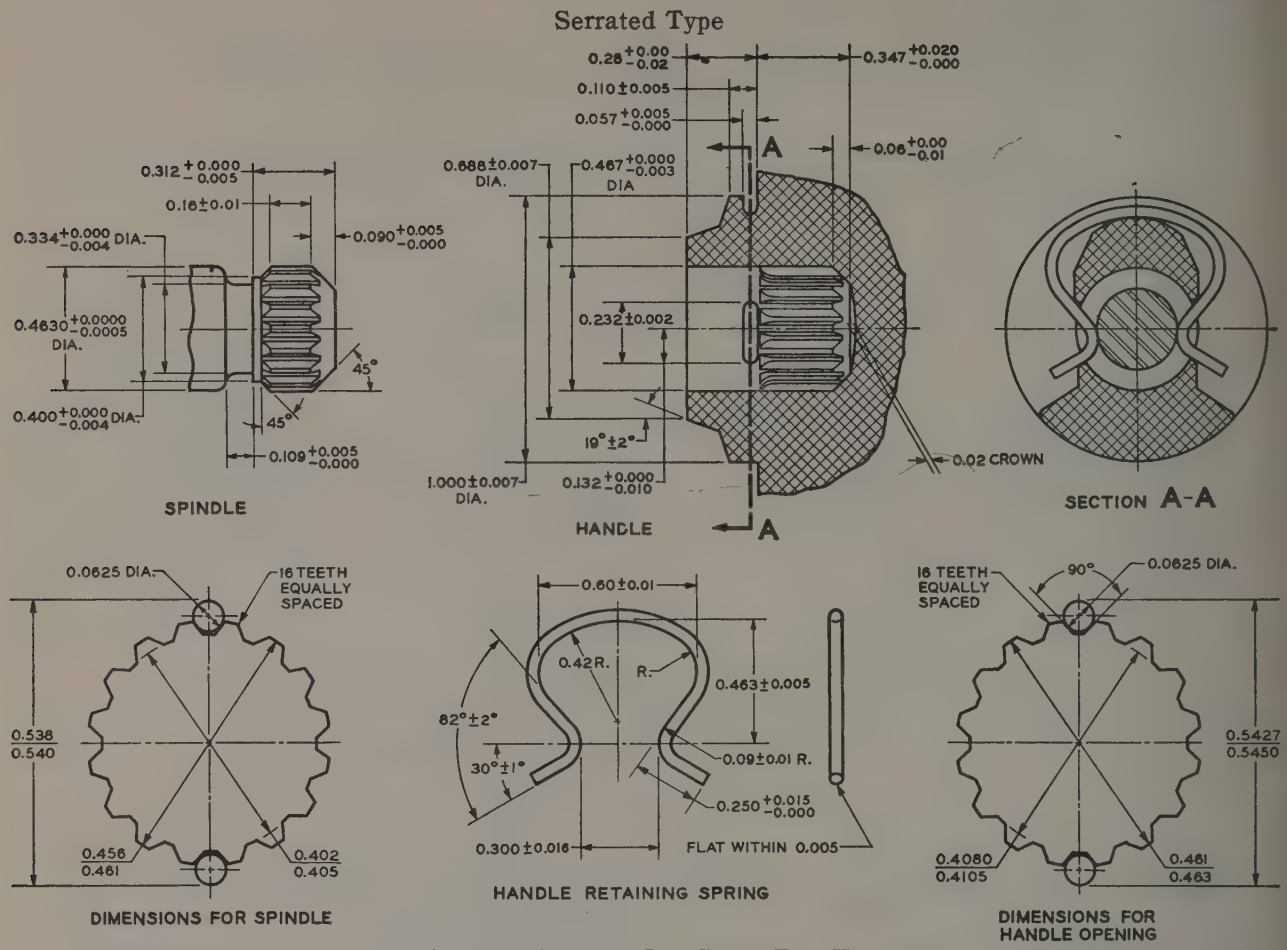


FIG. 3—SERRATION DATA FOR LOW-CLUTCH-TYPE HARDWARE

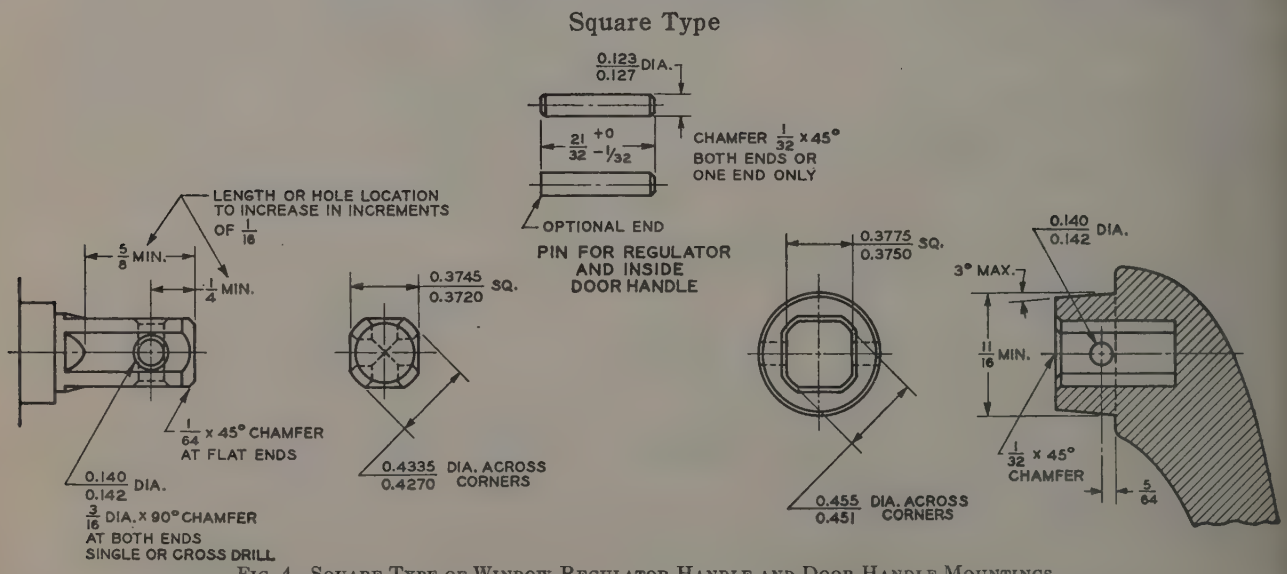

Square Type
PIN FOR REGULATOR AND INSIDE DOOR HANDLE
OPTIONAL END
LENGTH OR HOLE LOCATION TO INCREASE IN INCREMENTS OF 1/16
1/64 x 45° CHAMFER AT FLAT ENDS
3/16 DIA. x 90° CHAMFER AT BOTH ENDS SINGLE OR CROSS DRILL
0.4335 / 0.4270 DIA. ACROSS CORNERS
0.455 / 0.451 DIA. ACROSS CORNERS
3° MAX.
1/32 x 45° CHAMFER

FIG. 4—SQUARE TYPE OF WINDOW-REGULATOR-HANDLE AND DOOR-HANDLE MOUNTINGS

Method of mounting: cross pin

Material for pin for regulator and inside door handle is to be SAE 1010 cold-rolled steel or equivalent

(*Continued on next page.*)

Square Type

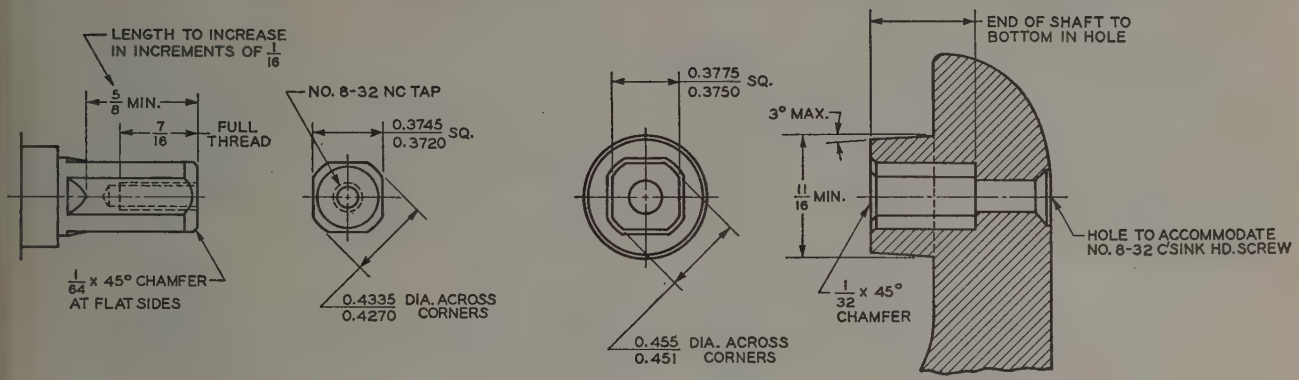

LENGTH TO INCREASE IN INCREMENTS OF 1/16
5/8 MIN.
7/16 FULL THREAD
1/64 x 45° CHAMFER AT FLAT SIDES
NO. 8-32 NC TAP
0.3745 SQ. 0.3720
0.4335 DIA. ACROSS 0.4270 CORNERS
0.3775 SQ. 0.3750
END OF SHAFT TO BOTTOM IN HOLE
3° MAX.
11/16 MIN.
HOLE TO ACCOMMODATE NO. 8-32 C'SINK HD. SCREW
1/32 x 45° CHAMFER
0.455 DIA. ACROSS 0.451 CORNERS

FIG. 5—SQUARE TYPE OF WINDOW-REGULATOR-HANDLE AND DOOR-HANDLE MOUNTINGS
Method of mounting: screw in face

Cylinder Locks and Keys

SAE Standard

Report of Passenger-Car Body Engineering Technical Committee approved June 1948.

Nomenclature—All key-operated locks on automotive vehicles, such as those used for locking ignition switches, doors, compartments, lids, and gasoline-filler caps, are to be designated as *cylinder-lock assemblies*. This name is to be preceded by the name of the specific part of the vehicle to be locked, such as *ignition-switch cylinder-lock assembly* or *door cylinder-lock assembly*.

The same words may be rearranged to conform to certain users' standard methods of naming parts, such as *assembly cylinder lock, ignition switch.*

Certain principal parts shall be named as shown in Figs. 1–4.

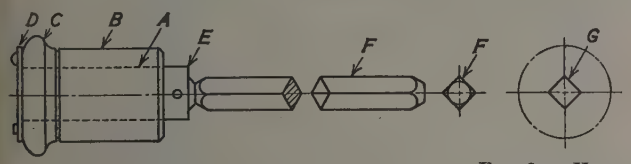


FIG. 1—DOOR CYLINDER-LOCK ASSEMBLY

FIG. 2 — HOLE FOR SHAFT IN DOOR LATCH

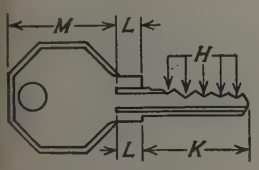


FIG. 3—PRIMARY KEY SET

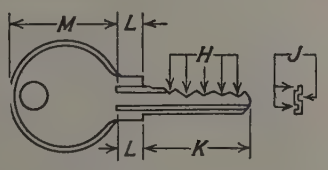


FIG. 4—SECONDARY KEY SET

A—Plug
B—Shell
C—Bezel
D—Keyhole cover
E—Joint
F—Shaft
G—Hole for shaft in latch
H—Bitting
J—Grooving
K—Blade
L—Shoulder
M—Bow

Dimensions—At the present time it is only considered advisable to establish standard dimensions on the shaft and the hole for shaft in door latch as follows:

Shaft, *F* ..... 0.170 to 0.190 in.
Hole for shaft, *G* ..... 0.195 to 0.201 in.

Lubrication and Cleaning—The following recommendation applies only to lubrication and cleaning of cylinder locks in service and does not apply to lock manufacturers.

1. Cylinder-lock assemblies should not be lubricated with oil or grease which would leave a gummy residue. Such residue impairs the action of the working parts and also collects harmful dirt and grit.

2. Before lubricating, the cylinder lock should be washed with ether alcohol or gasoline, either by removing the lock and submerging it or by blowing the alcohol or gasoline through the assembly with air.

3. After cleaning, the lock should be lubricated with flake graphite either by blowing it through the assembly with air or by working it in with the key. Extremely coarse graphite in which the flakes average over 1/32 in. should not be used.

Definition of Key Sets—It is recommended that the same key operate the ignition-switch lock and the vehicle-door locks. This to be designated as the *primary key set.*

A separate key will operate the luggage-compartment lid. This key may or may not operate the instrument-panel-compartment lid or other lock applications or both. In no case should more than three different kinds of key be furnished. All different keys, other than those of the primary set, will be designated as the *secondary key set.*

Shape of Key Bow—*Primary Key Set*—Polygonal in shape with flat faces and corners around the periphery of the bow.

Secondary Key Set—Periphery of bow to be a rounded shape such as oval or cloverleaf.

Bumper Heights

SAE Standard

Report of Parts and Fittings Division approved August 1922 and last revised by Bumper Technical Committee March 1947.

Under full rated load and with a full brake stop at 5 to 10 mph, passenger cars, station wagons, and half-ton trucks shall stop so that the tops of the front bumper guards do not dive below, nor any part of the lower edge of the rear-main-bumper bar between the treads lift above, a line 18.25 in. above the road level. This Standard implies the inclusion of front bumper guards on half-ton trucks.

Note: Designing engineers are urged to avoid specifying extreme radii for the top of the front-bumper vertical bar and the bottom of the rear-bumper main bar. Considerable care in this respect is needed, otherwise the antilocking feature of the recommended dimension will be nullified. The substantially vertical surface of the front vertical bar and of the rear main bar should be the recommended height above the ground in order to insure the safety to be gained from the nonlocking-bumper feature of the above recommendation.

Speedometers and Tachometers

SAE Recommended Practice

Report of Parts and Fittings Division approved January 1939 and last revised by Parts and Fittings Technical Committee January 1951.

[*This Recommended Practice is intended for use as the basis for drive-gear computation and compensation for errors, for performance and identification, and for flexible shaft-end constructions. It also differentiates between the drives intended for heavy-duty and those for light-duty applications.*]

Drive-Gear Computation and Compensation for Error—The number of vehicle wheel revolutions per mile is to be determined by the vehicle manufacturer and this information is to be used as a basis for speedometer calibration.

Car wheel revolutions are to be taken at 10, 30, 60, and top speed miles per hour.

Readings are to be taken over, and not less than, a half-mile straight course with a driver and one passenger.

Tire inflation when taking wheel revolutions is to be in accordance with the vehicle manufacturer's recommended pressures.

Check for wheel revolutions is to be made by means of a revolution counter attached to the speedometer flexible shaft, or an auxiliary flexible shaft attached to the rear wheel.

The speedometer odometer shall indicate one mile for every 1000 revolutions of the flexible shaft. Vehicle wheel revolutions at 60 mph will be used as a basis for gear computations for speedometer drives. Gears are to be computed as nearly accurate as possible to produce 1000 revolutions of flexible shaft per mile of travel at the above speed.

If it is found that wheel revolutions for various vehicle speeds show sufficient variation to make satisfactory speedometer calibration difficult, then it is to be considered necessary for the speedometer manufacturer, and acceptable to the vehicle manufacturer, that speedometer dials be printed to compensate for this error. See Table 1.

TABLE 1—*Performance and Identification*

Basic speeds, mph	10	30	60	90	120
Allowable limits in calibration, miles	+1 to −1	+2 to −0	+3 to −0	+4 to −0	+5 to −0
Basic speeds, mph, at 1000-rpm flexible shaft speed		60	62		64
Permissible calibration, mph		60 to 63	62 to 65		64 to 67
Color of marking		Green	White		Orange

This normal range as to speedometer performance is to be considered as a definite part of a completed instrument. Identification, if desired, will be by means of a round dot ⅜ in. diameter on the back of the speedometer case in a place easily seen and in colors listed in Table 1.

All kilometer speedometers shall be identified by stamping "Kilo" on the back of the speedometer case, unless identification of sufficient nature appears on the face dial.

Further identification shall be placed on speedometers, including a distinct stamping of model or part number of the instrument and the date of its manufacture.

Variations in speedometer readings due to temperature changes from 0 to 100 F, shall not exceed 4 mph at 1000-rpm shaft speed on mile speedometers. This variation shall not exceed 6.4 kmph at 1000-rpm shaft speed on kilometer speedometers.

All calibration of speedometers in production shall be made with the instrument in approximately the same angular position[1]

[1] This angular position is to be specified by the vehicle manufacturer and shall not be less than 5 deg with the vertical, the top of the instrument being nearest the front of the vehicle.

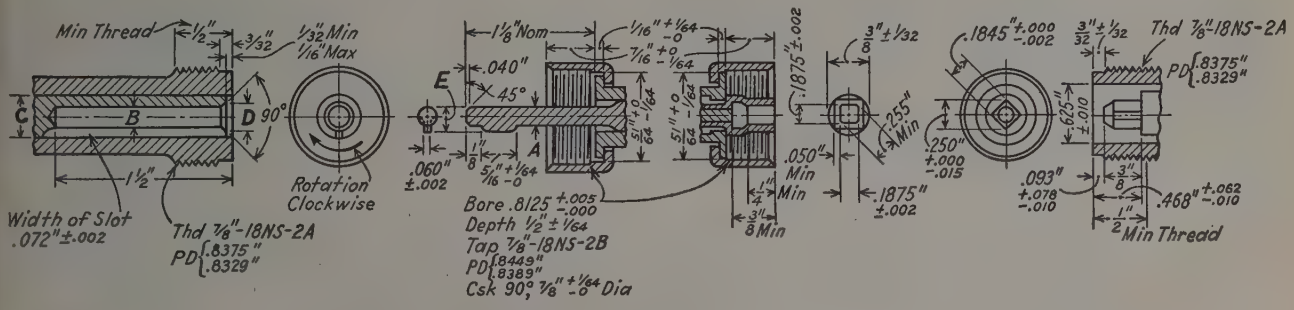
that it will have when mounted in the instrument board of the vehicle.

Vehicle manufacturers shall specify speedometer-gear-drive ratio and speedometer-calibration limits to give an overall error in speed indication between 0 and 7% above actual speed, at top speed of the vehicle at 70 F.

Fig. 1, Fig. 2, and Table 2 give dimensions for SAE heavy and SAE regular drives for speedometers and tachometers. When driving a tachometer to indicate engine rpm, the engine connection shall turn at half engine speed.

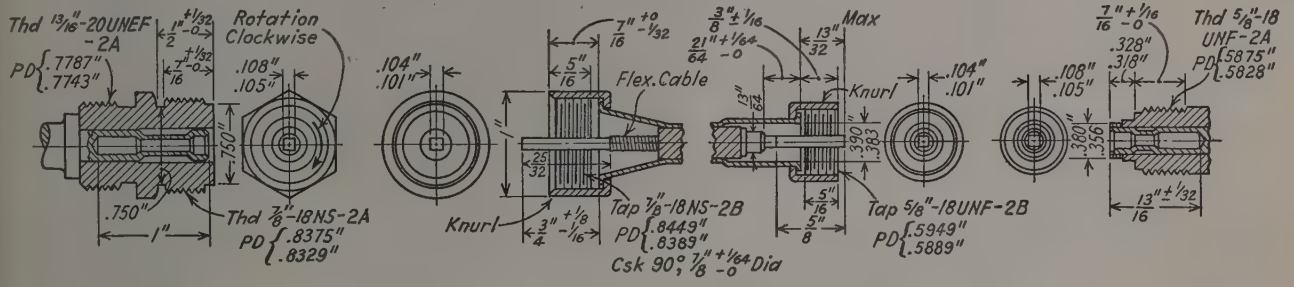
TABLE 2—*Dimensions for Speedometer and Tachometer Drives*

TYPE	SHAFT DIAMETER, *A*, +0.001, −0.002	DRILLED HOLE, *B*	SHAFT DIAMETER, *C*, MIN	C'SINK DIAMETER, *D*, +0, −1/32	TONGUE, *E*, +0.000, −0.010
SAE Heavy	0.187	0.191 (No. 11 drill)	3/8	1/4	0.235
SAE Regular	0.152	0.161 (No. 20 drill)	11/32	7/32	0.200



Engine Connection | Engine End of Drive Shaft | Instrument End of Drive Shaft | Instrument Connection

FIG. 1—SAE HEAVY DRIVE FOR SPEEDOMETERS AND TACHOMETERS



Engine or Transmission Connection | Engine or Transmission End of Drive Shaft | Instrument End of Drive Shaft | Instrument Connection

FIG. 2—SAE REGULAR DRIVE FOR SPEEDOMETERS AND TACHOMETERS

Chain Slots in Passenger-Car Wheels

SAE Recommended Practice

Report of Chain Slot Technical Committee approved December 1948.

A unit chain is a chain traction device designed for application to tires of vehicles when these vehicles are unable to proceed either forward or in reverse because of mud, snow, or the like.

Generally, the unit chains consist of two standard cross chains attached to a steel side plate or wire loop in such manner as to provide spacing of approximately 3½ in. between the cross chains. A webbing strap attached to one of the side plates is passed through the wheel slot and attached to the side plate on the opposite side of the tire with a buckle.

Unit chains are only to be used as *emergency* chains since they provide a minimum of intermittent tractive effort and can cause damage to axles, transmission, and differentials. Unit chains may be used for emergency operation but should be removed as soon as possible. Operation of unit chains on highways is dangerous because of the wide, unprotected space between the units.

It is recommended that passenger-car wheels have four chain slots to provide for the installation of emergency unit chains, the slots to be ⅜ in. minimum depth and 1½ in. minimum width, the edges to be smooth. The outer edge of chain slots should be the inner diameter of the rim or as close as possible to this diameter.

Passenger-Car-Trailer Couplings

SAE Recommended Practice

Report of Passenger Car Division approved January 1938 and last revised by Trailer Hitch Technical Committee March 1949.

[*This SAE Recommended Practice is applicable for use in connection with trailer regulation by State or Federal authorities having regulatory powers over motor vehicles, but its inclusion in State or Federal laws where flexibility of revision is lacking is discouraged.*]

Definition—The term *passenger-car trailer* is intended to refer to all types of trailers which are towed by the conventional passenger car (except buses). The following recommendations apply only to passenger-car trailers that are drawn by passenger cars and on which the coupling or couplings are located at the rear of the body of the towing vehicle. This Recommended Practice is intended primarily for ball-and-socket, ring-and-pintle, and clevis-and-pin types of coupling. It should not be construed as a limitation to these three basic types alone but should apply to any draft means designed to serve this purpose.

Coupling Nomenclature—The following have been adopted for uniformity in the terms used for the component parts of the trailer-coupling mechanism:

The *hitch* is that part of the connecting mechanism, including the coupling platform, which is attached to the towing vehicle.

The *coupling* is that part of the connecting mechanism by which the connection is actually made and including the supporting mechanism back to the trailer frame.

Trailer Classification—Class A: nonpassenger-carrying utility trailers, with a gross weight not to exceed 2000 lb.

Class B: all types, passenger- or nonpassenger-carrying trailers, with a gross weight of 2000 lb and not to exceed 5000 lb.

Class C: all types of trailers with a gross weight of 5000 lb and not to exceed 10,000 lb.

Coupling Classification—There shall be three sizes of couplings to cover all passenger-car trailers. The size of the coupling shall

be based on the gross trailer weight rather than the weight on the coupling. The No. 1 coupling shall be for Class A trailers, the No. 2 coupling for Class B trailers, and the No. 3 coupling for Class C trailers. This is not intended to limit the number or variety of couplings in a given class.

Hitch—The hitch and coupling platform shall be of such design as to conform to the minimum strength requirements of the coupling classification. Where a ball-and-socket type of coupling is used, the ball must conform to the minimum load ratings of the mating coupling.

Location of Hitch—Attachment to towing-car bumpers is limited to Class A trailers unless suitable means are provided for stiffening the bumper bar and transferring stress loading to the frame through the bumper brackets.

Provision for Safety—Couplings in all classes must be equipped with a manually operated mechanism so adapted as to prevent disengagement of the unit while in operation. In addition to this positive locking mechanism, the hitch shall be so designed that it can be disconnected regardless of the angle of the trailer to the towing vehicle.

Ratings—There shall be a standard minimum strength test or couplings by class as shown in Table 1.

TABLE 1—*Strength Ratings for Trailer Couplings*

TRAILER CLASSIFICATION	TRAILER-COUPLING DESIGNATION	MINIMUM BALL DIAMETER, IN. (WHERE BALL-TYPE HITCH IS USED)	MINIMUM BREAKING-POINT REQUIREMENTS, LB	
Class A	No. 1	1⅞	Longitudinal tension	6,000
		[a]S.A.	Longitudinal compression	6,000
		(11.04)	Transverse thrust	2,000
			Vertical tension	2,500
			Vertical compression	2,500
Class B	No. 2	2	Longitudinal tension	15,000
		[a]S.A.	Longitudinal compression	15,000
		(12.56)	Transverse thrust	4,000
			Vertical tension	7,000
			Vertical compression	7,000
Class C	No. 3	2 5/16	Longitudinal tension	30,000
		[a]S.A.	Longitudinal compression	30,000
		(16.80)	Transverse thrust	10,000
			Vertical tension	12,500
			Vertical compression	12,500

[a] Resulting surface area in square inches.

Passenger-Car-Trailer Data Plate

SAE Recommended Practice

Report of Passenger Car Division approved January 1938.

[*This SAE Recommended Practice has been adopted as the minimum information that should be furnished by the trailer manufacturer for identification purposes and to make the data available in a standard location on the trailer for inspection by customs or regulatory officials with the least inconvenience to the trailer owner.*]

The trailer manufacturer's identification plate in passenger-car trailers should be located in the jamb of the principal trailer door and should give the following data regarding the trailer:

1. Trailer manufacturer's name and address.
2. Trailer serial number (to correspond with the serial number on the trailer frame).
3. Trailer model.
4. Net total trailer weight (including standard equipment furnished by the trailer manufacturer).
5. Maximum gross weight on each wheel.
6. Maximum gross weight on the coupling tongue.

The detail design of the plate is left to the individual trailer manufacturer. The data required above will give the minimum information that should be available for identification purposes and for easy and uniform inspection.

Commercial-Vehicle Nomenclature

SAE Standard

Report of Commercial-Vehicle Nomenclature Technical Committee approved June 1948.

Vehicle—A vehicle is any single conveyance on wheels.

Motor Vehicle—A motor vehicle is any vehicle self-propelled or drawn by mechanical power, operated on the highways or natural terrain in the transportation of property or passengers.

Motor-Vehicle Chassis—A motor-vehicle chassis is a motor vehicle stripped of all essentials necessary for the accommodation of driver, property, or passengers.

4 x 2—A 4 x 2 motor vehicle is a two-axle motor vehicle equipped with four wheels, two of which are driving wheels.

4 x 4—A 4 x 4 motor vehicle is a two-axle motor vehicle equipped with four wheels, all of which are driving wheels.

6 x 2—A 6 x 2 motor vehicle is a three-axle motor vehicle equipped with six wheels, two of which are driving wheels.

6 x 4—A 6 x 4 motor vehicle is a three-axle motor vehicle equipped with six wheels, four of which are driving wheels.

6 x 6—A 6 x 6 motor vehicle is a three-axle motor vehicle equipped with six wheels, all of which are driving wheels.

(*Note:* Motor vehicles designed with other combinations of driving and nondriving axles are defined in the same numerical order.)

Motor Truck—A motor truck is a single self-propelled motor vehicle carrying its load on its own wheels and designed for the transportation of property.

Truck Tractor—A truck tractor is a motor vehicle designed primarily for drawing truck trailers and constructed so as to carry part of the weight and load of a semi-trailer.

Conventional Truck or Truck Tractor—A conventional motor truck or truck tractor is one with the driver's compartment and controls located at the rear of a hood-enclosed powerplant.

Cab-Forward Truck or Truck Tractor—A cab-forward motor truck or truck tractor is one with the driver's compartment and controls located forward of their position on the conventional front-end type of motor truck or truck tractor.

Off-Highway Motor Vehicle—An off-highway motor vehicle is any motor vehicle designed primarily for transporting property on natural terrain and may be of such size or weight as to be restricted from operation on highways by State laws or regulations.

Multistop Delivery Truck—A multistop delivery truck is one equipped with a fully enclosed body with driving compartment integral and especially designed for quick and easy ingress and egress.

Gantry Truck—A gantry truck is a motor truck so designed and constructed that it straddles the load to be transported and by means of an appropriate mechanism picks up the load and supports it during transportation.

Motor Bus—A motor bus is a single self-propelled motor vehicle designed for the transportation of ten or more passengers.

City-Type Motor Bus—A city-type motor bus is a motor bus designed to accommodate the maximum number of passengers, both seated and standing, within the body space.

Suburban-Type Motor Bus—A suburban-type motor bus is a motor bus designed primarily for maximum passenger seated load and equipped with overhead parcel racks.

Inter-City-Type Motor Bus—An inter-city-type motor bus is a motor bus designed for long-distance transportation of passengers with provision for the accommodation of their baggage.

Trolley Bus—A trolley bus is a motor bus electrically powered from overhead wires.

School Bus—A school bus is a motor bus equipped to carry school children.

Truck Trailer—A truck trailer is a motor vehicle, with or without auxiliary motive power, designed to be drawn by a motor vehicle.

Semi-Trailer—A semi-trailer is a truck trailer equipped with one or more axles and constructed so that a substantial part of its weight and load is carried by a truck tractor.

Full Trailer—A full trailer is a truck trailer constructed so that practically all of its weight and load rests upon its own wheels.

Dump Trailer—A dump trailer is a truck trailer provided with a body which can be tilted or otherwise manipulated to discharge its load by gravity.

Low-Bed Trailer—A low-bed trailer is a truck trailer equipped with or without a platform body and constructed to provide a low loading height and designed for the transportation of extremely heavy or bulky property.

Tank Trailer—A tank trailer is a truck trailer designed for the transportation of fluid commodities in bulk.

Passenger Trailer—A passenger trailer is a truck trailer designed primarily for the transportation of passengers.

Pole Trailer—A pole trailer is a truck trailer without auxiliary motive power, designed to be drawn by a truck or truck tractor and attached by means of a reach or pole, or by being "boomed" or otherwise secured to the drawing motor vehicle and intended for transporting long or irregularly shaped loads such as poles logs, pipes, or structural members which are capable generally of sustaining themselves as beams between supporting connections.

(*Note:* Wheel and axle complement: Two wheels are considered the complement of any axle regardless of whether they may be single- or dual-tire equipped.)

Single-Axle Truck Trailer—A single-axle truck trailer is a truck trailer equipped with one axle and two wheels.

Two-Axle Truck Trailer—A two-axle truck trailer is a truck trailer equipped with two axles and four wheels.

Three-Axle Truck Trailer—A three-axle truck trailer is a truck trailer equipped with three axles and six wheels.

Trailer-Converter Dolly—A trailer-converter dolly is an auxiliary axle assembly equipped with a lower fifth-wheel half, drawbar, and other necessary parts designed to convert a semi-trailer to a full trailer.

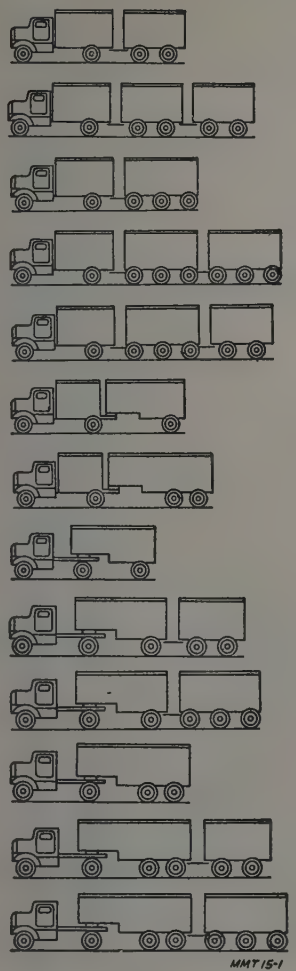
(*Note:* The vehicles defined in this list are used in combinations as illustrated in Figs. 1 and 2.)

Bodies—*Pick-Up Body or Express Body*—A pick-up body is an open box body with or without flare boards. A pick-up body is usually smaller than an express body.

Sedan Delivery—A sedan delivery is a passenger-car sedan-type body adapted to commercial use.

Panel Body or Van Body—A panel body or van body is a fully enclosed body. A panel body is usually smaller than a van body.

Open Van Body—An open van body is a body consisting of a platform and permanent solid front and sides with or without



1. Two-axle truck with two-axle full trailer in combination.
2. Two-axle truck with two-axle full trailers in combination.
3. Two-axle truck with three-axle full trailer in combination.
4. Two-axle truck with two three-axle full trailers in combination.
5. Two-axle truck with one three-axle and one two-axle full trailer in combination.
6. Two-axle truck with single-axle semi-trailer in combination.
7. Two-axle truck with two-axle semi-trailer in combination.
8. Two-axle truck tractor with single-axle semi-trailer in combination.
9. Two-axle truck tractor with single-axle semi-trailer and two-axle full trailer in combination.
10. Two-axle truck tractor with single-axle semi-trailer and three-axle full trailer in combination.
11. Two-axle truck tractor with two-axle semi-trailer in combination.
12. Two-axle truck tractor with two-axle semi-trailer and two-axle full trailer in combination.
13. Two-axle truck tractor with two-axle semi-trailer and three-axle full trailer in combination.

FIG. 1—TWO-AXLE TRUCK AND TRUCK TRACTOR GROUP

doors or tailgate and without a permanent top.

Platform Body—A platform body is a body without raised sides or covering.

Stake Body—A stake body is a platform body with readily removable stakes which may be tied together with chains, slats, or panels.

Rack Body—A rack body is a platform body with slatted sides to contain the load.

Dump Body—A dump body is a body which can be tilted or otherwise manipulated to discharge its load by gravity.

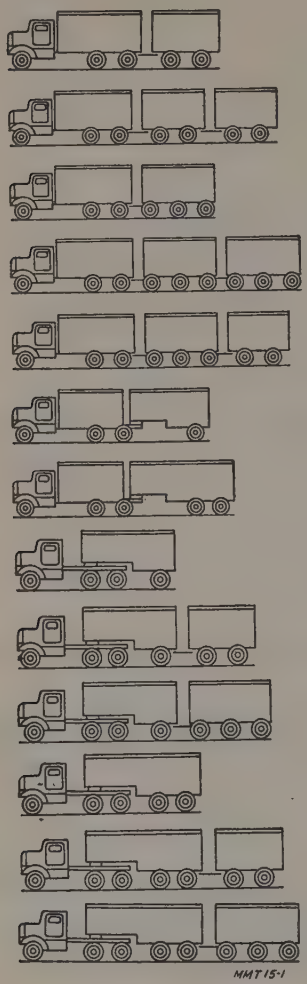
Tank Body—A tank body is a body designed for the transportation of fluid commodities in bulk.

Identification of Motor-Vehicle Combinations—Figs. 1 and 2 illustrate and identify combinations of motor vehicles. Fig. 1 applies to two-axle group, and Fig. 2 applies to three-axle group.

(Note: Two wheels are the complement of any axle regardless of the number of tires, whether singles, duals, or more.

Trucks and tractors may be either 4 x 2, 4 x 4, 6 x 2, 6 x 4, or 6 x 6. Additional combinations are possible by other wheel or axle arrangements.)

(*Continued on next page.*)



14. Three-axle truck with two-axle full trailer in combination.

15. Three-axle truck with two two-axle full trailers in combination.

16. Three-axle truck with three-axle full trailer in combination.

17. Three-axle truck with two three-axle full trailers in combination.

18. Three-axle truck with one three-axle and one two-axle full trailer in combination.

19. Three-axle truck with single-axle semi-trailer in combination.

20. Three-axle truck with two-axle semi-trailer in combination.

21. Three-axle truck tractor with single-axle semi-trailer in combination.

22. Three-axle truck tractor with single-axle semi-trailer and two-axle full trailer in combination.

23. Three-axle truck tractor with single-axle semi-trailer and three-axle full trailer in combination.

24. Three-axle truck tractor with two-axle semi-trailer in combination.

25. Three-axle truck tractor with two-axle semi-trailer and two-axle full trailer in combination.

26. Three-axle truck tractor with two-axle semi-trailer and three-axle full trailer in combination.

FIG. 2—THREE-AXLE TRUCK AND TRUCK TRACTOR GROUP

Certificates of Maximum Net Horsepower for Motor Trucks and Truck Tractors

SAE Standard

Report of Motorcoach and Motor Truck Division approved January 1941.

[*In the report of the SAE Motor-Truck Rating Committee on Ability Ratings published in the January 1940 issue of the SAE Journal, it was recommended that pounds per certified net brake horsepower delivered to the clutch or its equivalent be used as the index of the potential ability of a motor truck or combination. This report defined the term "certified net brake horsepower" in detail and recommended that certain data be provided to support the certification. The accompanying forms provide a method for the presentation of the data specified.*]

CERTIFICATE OF MAXIMUM NET HORSEPOWER

This is to certify that the truck identified as follows:
(truck tractor)

MAKE.....
MODEL.....
ENGINE MAKE.....
ENGINE MODEL.....

is in proper operating condition and adjustment, has a maximum net brake horsepower not less than..... at ..... rpm, after deducting power losses due to power-absorbing accessories checked on supporting data sheet on the back of this certificate.

(Signed).....
(Title).....
(Firm).....

Sworn to and subscribed before me this.....day of....., 19....
L. S.
Notary Public (County) (State)
My Commission expires.....

FIG. 1—CERTIFICATION FOR GASOLINE AND DIESEL ENGINES—FRONT OF FORM

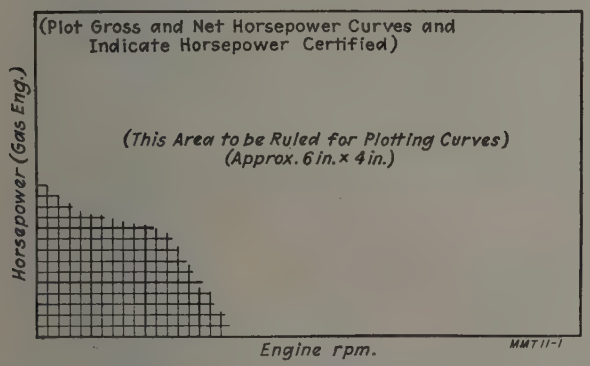

(Plot Gross and Net Horsepower Curves and Indicate Horsepower Certified)
(This Area to be Ruled for Plotting Curves)
(Approx. 6 in. x 4 in.)
Horsepower (Gas Eng.)
Engine rpm.
MMT11-1

FIG. 2—PERFORMANCE DATA SHEET FOR GASOLINE ENGINES—BACK OF FORM

Gasoline Engine—*Gross horsepower* is the brake horsepower determined under conditions as defined hereinafter by dynamometer test of the stripped engine—that is, the brake horsepower of the engine with only those accessories and attachments necessary to the functioning of the engine during this test.

Net horsepower is the brake horsepower delivered to the clutch, or its equivalent, with all accessories and attachments functioning (including exhaust pipe, muffler, and trail pipe) which are standard or regular equipment on the engine as installed in the particular chassis model. The manufacturer may determine the net horsepower by subtracting accessory power consumption from the gross brake horsepower or by direct test with accessories installed and functioning.

Horsepower shall be determined under conditions and in accordance with procedure prescribed by current SAE Standard Engine Test Codes for the type of engine under test.

Description of Engine and Equipment

1. Engine Make.....
2. Engine Model.....
3. No. of Cylinders.....
4. Bore.....in., Stroke..in.
5. Piston Displacement..cu in.
6. Compression Ratio.....
7. Inlet-Valve Clear Diam.[1] .....in.
8. Inlet-Valve Lift[1].....in.
9. Exhaust-Valve Clear Diam.[1] .....in.
10. Exhaust-Valve Lift[1].....in.
11. Inlet Valve Opens[1].....
12. Inlet Valve Closes[1].....
13. Exhaust Valve Opens[1].....
14. Exhaust Valve Closes[1].....
15. Max Spark Advance[1]....deg Retard.....deg

[1] If not poppet type, explain below

.....

.....

.....

.....

Power Absorbing Accessories, Equipment, and Attachments

In column A, check items which were functioning when gross horsepower was determined. In column B, check all additional items which were functioning when net horsepower was determined. List and check any additional items. For items not used, write "None".

	A	B		A	B
1. Oil Pump[1]			10. Air Filter		
2. Water Pump[2]			11. Governor		
3. Fan[1]			12. Generator		
4. Exhaust Pipe[1]			13. Vacuum Pump		
5. Muffler[1]			14. Compressor		
6. Trail Pipe			15.		
7. Fuel Pump			16.		
8. Ign Distributor[3]			17.		
9. Magneto[3]					

[1] Required.
[2] Required if watercooled.
[3] Either or both.

Fuel used in brake horsepower tests is to have octane rating equivalent to that of currently available "regular-price" gasolines.

Diesel Engine—*Gross horsepower* is the brake horsepower determined under conditions as defined hereinafter by dynamometer test of the stripped engine—that is, the brake horsepower

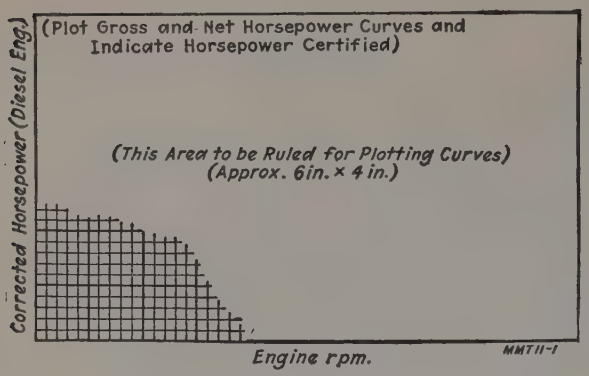

(Plot Gross and Net Horsepower Curves and Indicate Horsepower Certified)
(This Area to be Ruled for Plotting Curves)
(Approx. 6in. × 4 in.)
Corrected Horsepower (Diesel Eng.)
Engine rpm.
MMTII-1

FIG. 3—PERFORMANCE DATA SHEET FOR DIESEL ENGINES—BACK OF FORM

of the engine with only those accessories and attachments necessary to the functioning of the engine during this test.

Net horsepower is the brake horsepower delivered to the clutch, or its equivalent, with all accessories and attachments functioning (including exhaust pipe, muffler, and trail pipe) which are standard or regular equipment on the engine as installed in the particular chassis model. The manufacturer may determine the net horsepower by subtracting accessory power consumption from the gross brake horsepower or by direct test with accessories installed and functioning.

Corrected horsepower shall be determined under conditions and in accordance with procedure prescribed by current SAE Standard Engine Test Codes for the type of engine under test.

Description of Engine and Equipment

1. Engine Make..... 5. Bore.....in., Stroke...in.
2. Engine Model..... 6. Piston Displacement....cu in.
3. Cycle Strokes.....in. 7. Compression Ratio.....
4. No. of Cylinders.....

Power Absorbing Accessories, Equipment, and Attachments

In column A, check items which were functioning when gross horsepower was determined. In column B, check all additional items which were functioning when net horsepower was determined. List and check any additional items. For items not used, write "None".

	A	B		A	B
1. Lubrication Oil Pump[1]			9. Air Cleaner		
2. Fuel Transfer Pump			10. Governor[1]		
3. Fuel Injection Equipment[1]			11. Generator		
4. Water Pump[2]			12. Vacuum Pump		
5. Fan[1]			13. Compressor		
6. Exhaust Pipe[1]			14.		
7. Muffler[1]			15.		
8. Trail Pipe			16.		

[1] Required.
[2] Required if watercooled.

Fuel used in brake horsepower tests is to have 40 to 60 cetane rating.

Motor-Truck-Chassis Record Form

SAE Recommended Practice

Report of Motorcoach and Motor Truck Division approved January 1932.

Motor-Truck-Chassis Record Form

Order No.....
Model No.....
Chassis No.....
Wheelbase, in.....
Back of Cab to Center of Rear Axle, in.....
Weight Distribution
Front Wheels, %.....
Rear Wheels, %.....
Chassis Weight, lb.....
Body Weight, lb.....
Payload Weight, lb.....
Gross Weight, lb.....

UNIT	DESCRIPTION
ENGINE	
Make	
Model	
Serial No.	
Number of Cylinders	
Bore and Stroke, in.	
Cylinder Head, Type	
Cyl-Head Gasket, Thickness	
Spark Plugs, Size and Type	
Valve Stem Diam, Inlet	
Exhaust	
Valve Guide Bushing, Inlet	
Exhaust	
Pistons, Make and Type	
Material	
Clearance at Top, in.	
Clearance at Skirt, in.	
Piston-Pins Diameter, in.	
Clearance, in.	
Piston Rings, Make	
No. of Compression Rings	
Size and Clearance	
Number of Oil Rings	
Size and Clearance	
GOVERNOR	
Make and Type	
Part or Serial No.	
Setting Recommended	
Speed, rpm	
FUEL SYSTEM	
Tank, Capacity	
Overall Dimens, in.	
Location	
Gasoline Gage,	
Make and Type	
Vacuum Tank	
Make and Type	
Fuel Pump,	
Make and Type	
Carburetor, Make	
Model and Type	
Size, in.	
Air Cleaner, Make	
Model and Type	
EXHAUST SYSTEM	
Muffler, Make and Type	
COOLING SYSTEM	
Radiator, Make and Type	
Capacity	
Radiator Shutters	
Fan, Type	
Belt, Type	
Water Pump, Type	
OILING SYSTEM	
Pressure Gage	
Chassis Lubrication, Type	
Oil Filter, Make and Type	
Rectifier, Type	
ELECTRIC SYSTEM	
Magneto, Make and Type	
Impulse Starter, Type	
Magneto Coupling, Type	
Generator, Make and Type	
Voltage	
Cut-Out, Make and Type	
Unit with Regulator?	
Starting Motor	
Make and Type	
Voltage	
Starter Switch	
Drive	
Battery, Make and Type	
Voltage	
Ampere Hours	
Overall Dimensions	
Distributor	
Make and Model	
Spark Coil, Make	
Ammeter, Make	
Ignition Switch, Make	
Headlamps	
Make and Type	
Lens, Make and Type	
Size, in.	
Stoplight, Make	
Fuses, Size	
CLUTCH	
Make and Type	
Number of Driving Discs	
Number of Driven Discs	
Release Bearing, Make	
Type and Size	
Pilot Bearing, Make	
Type and Size	
TRANSMISSION	
Make and Type	
Auxiliary Transmission	
Fitted for Power Take-Off?	
DRIVE	
Propeller Shaft, Long	
Length Overall, in.	
Universal Joints, Make	
Propeller-Shaft Center	
Bear.—Make and Type	
Propeller Shaft, Short	
Length Overall, in.	
Universal Joints, Make	
Sprockets, No. of Teeth	
Front	
Rear	
Drive Chains, Make and	
Type—Size, in.	
Jackshaft, Assembly No.	
Gear Ratio	
CONTROL	
Steering-Gear Assembly	
Make	
Type	
FRONT AXLE	
Assembly, Part No.	
Wheels, Make and Type	
Tires, Make and Type	
Size	
Rim, Type	
Wheel Bearings, Make	
Inner, Size	
Outer, Size	
Hub Assembly, Type	
REAR AXLE	
Assembly, Part No.	
Wheels, Make and Type	
Tires, Make and Type	
Size	

(*Continued on next page.*)

Motor-Truck-Chassis Record Form (Concluded)

UNIT	DESCRIPTION	UNIT	DESCRIPTION	UNIT	DESCRIPTION
Rim, Type		SPRINGS		BODY	
Wheel Bearings, Make		Front, Make and Type		Cab, Make and Type	
Inner, Size		Rear, Make and Type		Body, Make and Type	
Outer, Size		Helper Springs			
Hub Assembly, Type					
Differential, Type		ODOMETER		EQUIPMENT	
Differential Housing, No.		Hubodometer		Hoist, Make and Type	
Type		Make and Type		Power Take-Off	
Gear Ratio		Speedometer,		Power-Take-Off Mounting	
		Make and Type		Tire Pump, Make	
		Pinion Gear		Winch, Make and Type	
FRAME		Swivel Joint		Capacity	
Make and Serial No.		Drive Gear		Driving-Tower Assembly	
Special Members		Shaft		Shock Absorbers, Make	
		Elbow		Horn	
		Adapter			
BRAKES		Odometer Shaft			
Foot Brakes, Make and Type		Length, in.			
Hand Brakes, Make and Type		Driven from			

Description of Features

Preventive Maintenance and Inspection Procedure

SAE Recommended Practice

Report of Transportation and Maintenance Technical Committee approved July 1947.

Experience accumulated by operators of large fleets of vehicles indicates a need for the adoption of a preventive maintenance and inspection schedule. The accompanying recommendation provides a broad, flexible basis for periodic maintenance of all types of automotive vehicles. Used as a guide, this schedule can be adapted by any vehicle operator, after study of past experience in his own service, to fit his particular operating conditions and types of vehicles.

Depending on operating conditions, either a time or mileage basis may be used for scheduling preventive maintenance and inspections. Many fleets commonly use the intervals between such maintenance and inspection services shown in Table 1.

A—The *A* maintenance service is designed to cover the items and work normally required every day or each time the vehicle leaves (or enters) the garage. Many of the items are, or should be, noted automatically by the driver or garageman.

TABLE 1—*Maintenance Service Intervals*

TYPE OF VEHICLE	*A*	*B*	*C*	*D*	*E*
		Miles	Miles	Miles	Miles
Passenger cars	Daily	1,000 to 2,000	4,000 to 6,000	30,000 to 50,000	60,000 to 100,000
Light trucks, stop-and-start service	Daily	500 to 2,000	3,000 to 5,000	20,000 to 30,000	40,000 to 60,000
Light trucks, long-haul service	Daily	1,000 to 2,000	4,000 to 6,000	40,000 to 60,000	80,000 to 120,000
Heavy trucks, stop-and-start service	Daily	500 to 2,000	3,000 to 5,000	30,000 to 40,000	60,000 to 80,000
Heavy trucks, long-haul service	Daily	1,000 to 2,000	4,000 to 6,000	40,000 to 60,000	80,000 to 120,000
Small buses, city service	Daily	1,000 to 2,000	3,000 to 5,000	30,000 to 40,000	60,000 to 80,000
Small buses, cross country	Daily	1,000 to 2,000	4,000 to 6,000	40,000 to 60,000	80,000 to 120,000
Large buses, city service	Daily	1,000 to 2,000	4,000 to 6,000	40,000 to 60,000	80,000 to 120,000
Large buses, cross country	Daily	1,000 to 2,000	4,000 to 6,000	40,000 to 60,000	80,000 to 120,000

(*Continued on next page.*)

B—The *B* maintenance service is primarily designed to fit the lubrication period. Many of the items shown are, or should be, noted by the lubrication man during greasing operations or while driving the vehicle to and from the lubrication rack or pit. The type of lubricants and lubrication equipment used, the design of the vehicles, and the operating conditions all affect the interval between *B* maintenance-service periods.

C—The *C* maintenance service includes, in addition to the function of *B*, most of the adjustments and tests plus a heavy or physical inspection with repairs. It may involve replacement in order to obtain the necessary adjustment or test results. It should be kept in mind that the success of any preventive maintenance and inspection procedure depends not merely on finding the defect but on the correction, adjustment, or replacement in time to save man hours and material. The time involved on this *C* maintenance service depends upon the vehicle design, the shop equipment, special tools, and the working conditions. It is practically impossible to make a satisfactory inspection of many parts until they have been properly cleaned.

D—The *D* maintenance service is designed to fit the more extensive repairs, such as replacement of piston rings, engine-bearing adjustment, heavy-unit replacement, in which more time and equipment is required than on the *C* service. The mileage interval between *D* maintenance-service periods will vary considerably, and it is recommended that the vehicle be assigned to *D* service as the result of tests made on *C* service.

E—In many types of service, it is desirable to schedule complete and comprehensive vehicle overhauls at periodic intervals. The *E* maintenance schedule can readily be adapted to specific vehicle operations requiring this type of service. Vehicle design, operating conditions, and quality of the *A*, *B*, *C*, and *D* maintenance services are the primary factors affecting the need for an *E* service schedule. These factors also affect the amount of work required on that schedule, and the time or mileage interval selected for *E* maintenance service.

Code:

A—Adjustments
H—Heavy or physical inspection or repair
L—Light or visual check-up
O—Oil, lubricate, or grease
R—Replacements, rebuild, or recondition
T—Tests

GROUP NO. 1—*Axle, Front*

ITEM	MAINTENANCE SERVICE				
	A	*B*	*C*	*D*	*E*
1-A1. Axle, center	—	L	H	H	R
1-A2. Axle and wheel alignment	—	L	TA	TA	TA
1-B1. Brake spider	—	L	H	H	R
1-S1. Steering knuckle and pins	—	OL	OHT	OH	R
1-S2. Steering arms	—	L	H	H	R
1-T1. Tie-rod assembly	—	AOL	AOH	AOH	R
1-T2. Thrust bearings	—	OL	OH	OH	R

GROUP NO. 2—*Axle, Rear*

ITEM	MAINTENANCE SERVICE				
	A	*B*	*C*	*D*	*E*
2-A1. Axle shaft	L	L	H	R	R
2-D1. Differential housing	—	OL	OH	OH	R
2-D2. Differential gears	—	L	L	H	R
2-D3. Differential bearings	—	—	L	AH	R
2-H1. Housing tube and spider assembly	—	L	L	H	R
2-P1. Pinion shaft and worm oil seals	—	L	L	AH	R
2-R1. Radius rods	—	L	H	H	R
2-W1. Wheel bearings oil seal	—	L	L	H	R

GROUP NO. 3—*Body and Cab*

ITEM	MAINTENANCE SERVICE				
	A	*B*	*C*	*D*	*E*
3-B1. Bumpers	—	L	H	H	H
3-C1. Cross members	—	L	H	H	H
3-C2. Curtains	—	L	H	H	H
3-D1. Doors	T	OLT	OAH	OAH	R
3-D2. Door engine (air) and mounting	—	OLT	OAH	OAH	R
3-D3. Door controls	T	OLT	OAH	OAH	R
3-E1. Engine housing, hood, and splash pan	—	L	H	H	R
3-F1. Frame body (or chassis)	—	L	H	H	H
3-F2. Fenders	L	L	H	H	H
3-F3. Flooring	L	L	H	H	H
3-F4. Fire extinguisher	—	L	TH	TH	TH
3-F5. Fifth wheel (tractor and semi-trailers)	—	OL	OH	OH	R
3-I1. Instrument panel speedometer, etc.)	—	L	H	H	H
3-L1. Landing gear (semi-trailers)	—	OL	OH	OH	R
3-L2. License plates and mountings	L	L	H	H	H
3-M1. Mirrors	L	L	H	H	H
3-P1. Exterior side panels	—	L	H	H	H
3-P2. Exterior roof panels	—	L	H	H	H
3-P3. Interior panels	—	L	H	H	H
3-P4. Paint	L	L	H	H	R
3-R1. Running boards	L	L	H	H	H
3-S1. Destination signs	L	L	H	H	R
3-S2. Seats	L	L	H	H	R
3-S3. Stanchion and grab rail	—	L	H	H	R
3-S4. Steps	—	L	H	H	R
3-S5. Sun visors	—	L	H	H	H
3-V1. Ventilators	—	TL	TH	TH	R
3-W1. Windows, glass	—	L	H	H	H
3-W2. Windshield-wiper motor and blades	L	TOL	TOH	TOH	R

(*Continued on next page.*)

GROUP NO. 4—*Brake System*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
4-B1.	Brake blocks or lining	—	TL	THA	THA	THA
4-B2.	Brake shoes, springs, rollers, and pins	—	LO	OH	R	R
4-B3.	Brake valve	T	TL	TH	R	R
4-B4.	Brake controls, pedal, and linkage	—	OL	OH	OH	R
4-B5.	Brake chambers, mountings, and parts	—	TL	TH	TH	R
4-C1.	Cams, brake	—	ALO	AOH	R	R
4-C2.	Compressor (air), drive and mounting	OL	OLT	AOTH	AOTH	R
4-C3.	Cylinders and hydraulic lines	—	L	H	H	R
4-D1.	Drums, brake	—	L	H	H	H
4-G1.	Governor	—	TL	TH	AH	R
4-H1.	Flexible brake-chamber hose	—	TL	TH	TH	R
4-H2.	Hand-brake controls	T	OTL	OTH	OTH	R
4-I1.	Interlock cylinder	—	OTL	OTH	OTH	R
4-L1.	Lines and fittings, air and water	—	L	HT	HT	HT
4-M1.	Magnetic air valve	—	L	TH	TH	R
4-M2.	Master cylinder (hydraulic)	—	OL	OL	OH	R
4-Q1.	Quick-release valve	—	TL	TH	TH	R
4-P1.	Pressure regulating valve	—	TL	TH	TH	R
4-R1.	Relay valve	—	L	TH	TH	R
4-S1.	Slack adjusters	—	OA	OAL	OAH	R
4-S2.	Safety valve	—	L	H	H	R
4-T1.	Tanks, air valves, and gages	Drain	L	TH	TH	R
4-T2.	Trailer brakes	—	TL	TH	TH	R
4-V1.	Vacuum booster cylinder	—	L	OH	OH	R

GROUP NO. 5—*Clutch*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
5-A1.	Adjusting ring	—	T	A	H	R
5-B1.	Bearing	—	O	OL	OH	R
5-C1.	Clutch assembly	T	LAO	HAO	R	R
5-C2.	Clutch control	T	TLOA	THAO	THAO	R
5-C3.	Clutch disk and facings	—	T	T	R	R
5-C4.	Clutch pressure ring	—	—	—	H	R

GROUP NO. 6—*Cooling System*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
6-F1.	Fan belts and adjusting screws	L	AH	AH	AH	R
6-F2.	Fan, mounting parts and drive	—	LO	HO	HO	R
6-H1.	Heater, water and controls	—	OTL	OTH	OTH	R
6-H2.	Hose, radiator	—	L	H	R	R
6-P1.	Pump couplings, water	—	L	H	R	R
6-P2.	Pumps, water	—	OLA	OHA	R	R
6-R1.	Radiator	(Fill)	L	H	H	R
6-R2.	Radiator mounting parts	—	L	H	H	H
6-R3.	Radiator shutter and controls	L	OTH	OTH	OTH	R
6-T1.	Temperature indicators	—	L	H	AH	R
6-T2.	Thermostats	—	L	H	AH	R
6-W1.	Water lines	—	L	H	H	H

GROUP NO. 7—*Electrical System*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
7-A1.	Apparatus box or regulator	—	TL	TAH	TAH	R
7-A2.	Ammeter (gen. charge)	T	TL	TH	TH	TH
7-B1.	Battery, cables and mounting	—	TL	TH	TH	TH
7-B2.	Buzzer and cord	T	TL	TH	TH	TH
7-C1.	Coil	—	L	HT	HT	R
7-C2.	Condenser	—	L	HT	HT	R
7-C3.	Control equipment (electric drive)	T	TL	TAH	TAH	R
7-D1.	Distributor	—	OTL	OATH	R	R
7-F1.	Fuses	—	TL	TL	TH	TH
7-G1.	Generator, drive, and mounting (low voltage)	T	OTL	OAH	R	R
7-G2.	Generator (electric drive)	—	OL	OHT	OHT	R
7-H1.	Heater and ventilator motors	—	TLO	THO	THO	R
7-H2.	Headlamps	T	TL	AH	AH	AH
7-H3.	High tension ignition wire	—	L	H	H	R

(*Continued on next page.*)

GROUP NO. 7—*Electrical System (Continued)*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
7-H4.	Horn, wire and button	T	TL	TH	TH	R
7-L1.	Lights	T	TL	TH	TH	TH
7-M1.	Magneto	—	TL	TAH	R	R
7-M2.	Motor (electric drive)	—	OL	OHT	OHT	R
7-S1.	Spark plugs	—	TL	AH	R	R
7-S2.	Starting motor and cables	T	OTL	OTH	R	R
7-S3.	Switches	T	TL	TH	TH	TH
7-S4.	Stop light switch	T	T	TL	TH	R
7-T1.	Turn signals (directional)	T	TL	TH	TH	R
7-W1.	Wiring	—	L	H	H	H
7-W2.	Windshield wiper (electric)	—	TOL	TOH	TOH	R

GROUP NO. 8—*Engine*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
8-A1.	Accessory shaft and pulley	—	—	AL	AH	R
8-B1.	Bell housing	—	L	H	H	R
8-C1.	Camshaft	—	L	AH	AH	R
8-C2.	Connecting rods	—	L	L	AH	R
8-C3.	Crankcase and main bearings	L	L	L	AH	R
8-C4.	Crankshaft	—	—	—	H	R
8-C5.	Cylinder block	L	L	H	H	R
8-C6.	Cylinder head	L	L	HT	RT	R
8-C7.	Cylinder compression	—	—	T	T	T
8-E1.	Engine cranking parts	—	TLO	THO	THO	R
8-E2.	Engine to compressor drive	—	L	H	H	R
8-E3.	Engine mounting parts	—	L	H	H	R
8-F1.	Flywheel, ring gear	—	L	L	H	R
8-G1.	Gear cover and adjusting screws	—	L	AH	AH	R
8-M1.	Manifold and heat control	—	L	H	H	R
8-O1.	Oil filter and element	L	L	H	R	R
8-O2.	Oiling system and gage	LT	LT	HT	HT	R
8-O3.	Oil pan	LO	LO	HO	RO	R
8-P1.	Piston rings and pins	—	L	LT	R	R
8-T1.	Timing gears	—	L	AL	AH	R
8-V1.	Valve and lifter parts	—	L	AHT	RA	R

GROUP NO. 9—*Frame Springs and Mounting*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
9-H1.	Hanger brackets	—	L	H	H	H
9-S1.	Shackle bars	—	L	H	H	R
9-S2.	Shackles and pins	—	OL	OH	OH	R
9-S3.	Spring U-bolts	—	L	H	H	H
9-S4.	Springs and center bolts	—	L	H	H	R
9-S5.	Shock absorbers	—	L	H	H	R
9-T1.	Torque rods	—	OL	OHA	OHA	R

GROUP NO. 10—*Fuel and Exhaust System*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
10-A1.	Air cleaner	—	HO	HO	HO	R
10-B1.	Blower	—	LO	HO	R	R
10-C1.	Crankcase air breather and connections	—	L	H	H	R
10-C2.	Carburetor	—	AL	AH	R	R
10-C3.	Carburetor controls	T	OL	OH	OH	R
10-C4.	Choke	T	TL	TH	AH	R
10-E1.	Exhaust and tail pipe	—	L	H	H	H
10-F1.	Fuel pump (gasoline)	—	TL	TH	R	R
10-F2.	Fuel pump (diesel)	—	L	H	H	R
10-G1.	Governor	—	AL	AH	R	R
10-G2.	Gas tank and fuel lines	(Fill)	L	H	H	H
10-G3.	Gage, fuel	L	L	L	H	H
10-I1.	Injectors	—	TL	TH	R	R
10-M1.	Mufflers and hanger brackets	—	L	H	H	H
10-S1.	Strainers (all fuel) and filters	—	L	H	H	R
10-V1.	Vacuum tank	—	TL	TH	TH	R

GROUP NO. 11—*Special Equipment*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
11-F1.	Flares	—	L	H	H	H
11-R1.	Reflectors	L	L	H	H	H

GROUP NO. 12—*Steering*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
12-D1.	Drag links	—	OL	OAH	R	R
12-S1.	Steering arm	—	L	H	H	R
12-S2.	Steering wheel	—	L	H	H	H
12-S3.	Steering gear assembly	—	OTL	OTH	OTH	R

(*Continued on next page.*)

GROUP NO. 13—*Transmission*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
13-C1.	Cooler (hydraulic)	—	L	H	H	R
13-C2.	Countershaft assembly	—	L	H	AH	R
13-G1.	Gears (transmismission)	—	L	L	H	R
13-P1.	Power-take-off equipment	—	OL	OH	OH	R
13-T1.	Transmission cover and assembly	—	OL	OH	OH	R
13-T2.	Transmission case and bushing assembly	—	OL	OH	OH	R
13-T3.	Transmission control	—	OTL	TOH	TOH	R
13-T4.	Transmission cross shaft	—	OL	OH	OH	R
13-T5.	Turbine (hydraulic)	—	OL	OH	OH	R

GROUP NO. 14—*Propeller Shaft*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
14-D1.	Drive shaft	—	OL	OH	OH	R
14-H1.	Hanger bearing and mounting	—	OL	OH	OH	R
14-U1.	Universal joints	—	OL	OH	OH	R

GROUP NO. 15—*Wheels, Rims, and Tires*

ITEM		MAINTENANCE SERVICE				
		A	*B*	*C*	*D*	*E*
15-B1.	Bearings	—	—	OTL	OAH	R
15-H1.	Hub cap	—	L	H	R	R
15-H2.	Hubodometer	—	L	H	H	R
15-R1.	Rims, studs and nuts	L	H	H	H	R
15-S1.	Spider	—	L	H	H	R
15-T1.	Tires	L	TL	TH	TH	TH

Maintenance Instruction Cards for Motor Vehicles

SAE Recommended Practice

Report of SAE-ODT Committee No. 17 approved January 1943.

[*The purpose in formulating a standard method for presenting the servicing instructions of motor-vehicle parts, accessories, and tool manufacturers is to provide vehicle operators with a uniform guide to maintenance and servicing work, combining all operations in a single card index for use in the shop. This method will enable a mechanic, when drawing from the tool-room material and equipment for a job, also to draw a card showing exactly how that job should be done. Provisions are included for filing data on parts, accessories and tools, including the use, adjustment, and care of tools, under 16 parts groups, classified by motor-vehicle makes and models, with essential information on the vehicles themselves.*]

Standard Practice Instruction Cards

Size—14 x 18 in.

Material—A high-grade white tag stock which weighs at least 111 lb per 500 sheets, 22½ x 28½ in.

Minimum Size of Type—No type smaller than 12 point to be used in any text.

Grease-Proof Treatment—Instruction cards to be treated with lacquer or other suitable finish so as to withstand and accommodate themselves to handling by greasy hands, and so that grease can readily be wiped off without impairment of the cards.

Indexing and Filing Practice Instructions

1. *Vehicle Guide and Index Cards*—Vehicle guide and index

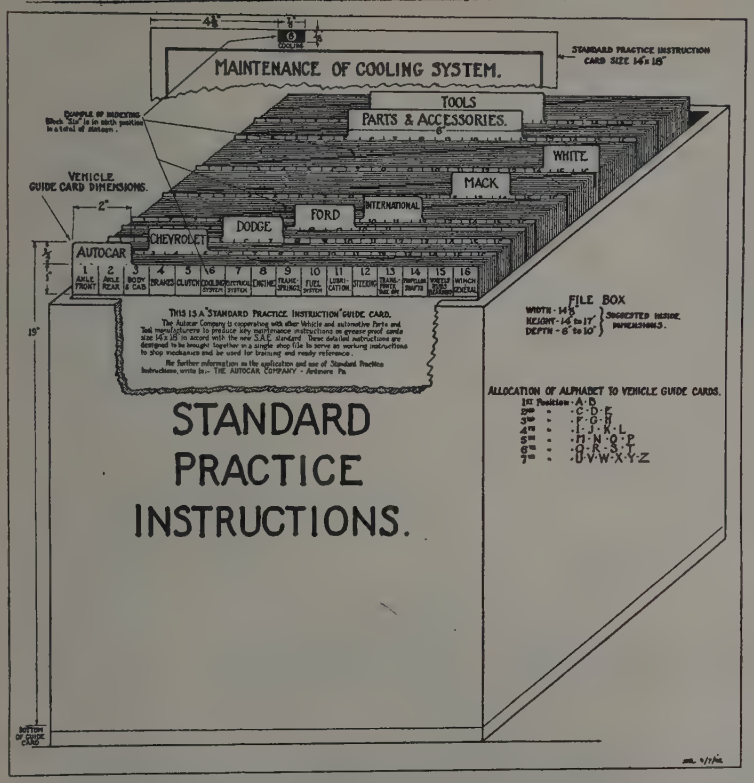


FIG. 1—INDEXING AND FILING SYSTEM FOR STANDARD PRACTICE INSTRUCTIONS

Note—It may be desirable to show company identification at the top of the card as well as models to which the card applies

cards will carry the manufacturer's name on the tab and will carry the following numbered index headings across the top of the card, as shown in Fig. 1:

1. Axle Front
2. Axle Rear
3. Body and Cab
4. Brakes
5. Clutch
6. Cooling System
7. Electrical System
8. Engine
9. Frame Springs
10. Fuel System
11. Lubrication
12. Steering
13. Trans-Power Take-Off
14. Propeller Shafts
15. Wheels, Hubs, Bearings
16. Winch-General

The guide cards will carry the manufacturer's name in position according to the following allocation of the alphabet:

1st Position—A-B
2nd Position—C-D-E
3rd Position—F-G-H
4th Position—I-J-K-L
5th Position—M-N-O-P
6th Position—Q-R-S-T
7th Position—U-V-W-X-Y-Z

Data on Vehicle Guide Card—The vehicle guide card may be used for tabulating data on various models. It may also carry an explanation of the standard practice instructions.

The suggested note on the guide card (see Fig. 1) is purely optional but is proposed with the idea of getting the interested operator to write the manufacturer and ask how he can use the instruction cards to the fullest advantage.

This offers the manufacturer the opportunity of encouraging the operator to set up a definite mechanic training program and to bring to the operator's attention work such as is now being carried on by SAE on this same topic—Training of Mechanics.

2. *Index Block at Top of Each Standard Practice Instruction*—Each standard practice instruction card will carry an index block at top of the card, located so that it will register with the index item on the guide card to which the instruction applies. Thus a card devoted to maintenance of the cooling system (Item 6 on the index card) would have an index block located in the sixth position and similarly numbered.

3. *Identification at Bottom of Card*—See Fig. 1. Each instruction card will carry a legend at bottom described by the following:

(a) That it is a standard practice instruction conforming to the SAE Standard.

(b) Name and address of the manufacturer who prepared the instruction.

(c) Copyright notice if desired.

4. *Parts and Accessories Guide Card*—The parts and accessories guide card will carry the same sixteen index headings used on the vehicle guide card.

Standard practice instructions prepared for direct distribution by parts and accessory manufacturers are to be filed according to index number back of the main guide card "Parts and Accessories."

If the instruction is distributed indirectly through some vehicle manufacturer and applies specifically to the latter's product, then it would be filed in its index block position back of the vehicle manufacturer's guide card.

5. *Tools Guide Card*—The tools guide card will carry the same sixteen index headings used on the vehicle guide card.

Standard practice instructions on the use, adjustment, and care of maintenance tools will carry an index block number at the top of the instruction which will tie in with the purpose of the tool and will be filed back of the general guide card—"Tools." Thus a valve-refacing machine is an engine tool and would be indexed with a No. 8 block. Supplementary identification at the top of the card could include the name of the article and the manufacturer, thus: Hall Valve-Refacing Machine.

Motor-Truck *CA* Dimensions

SAE Recommended Practice

Report of Frames Division approved February 1924 and last revised by Motorcoach and Motor Truck Division January 1941.

Frame Width—The nominal outside width of motor-truck frames shall be 34 in. with a maximum tolerance of plus 5/8 in., minus 0.

Frame Length—The *CA* dimensions (distance from extreme back of cab to centerline of rear axle) of four-wheel motor trucks, measured with the chassis unloaded, shall be 39, 48, 60, 72, 84, 96, 108, 120, 132, 144, and 156 in. The tolerance on the *CA* dimensions shall be plus 1 in., minus 0, to avoid possible interference between the cab and the body.

The *CA* dimension of six-wheel motor trucks shall be the same as those for four-wheel trucks and shall be measured from the extreme back of cab to a line midway between the two rear axles, expressed as a hyphenated figure, the first unit of which shall be the standard *CA* dimension as above defined. The second unit shall be the distance between the two rear axles and is to be given by the vehicle manufacturer as information only.

Truck-Tractor Trailer Clearances

SAE General Information

Report of Motorcoach and Motor Truck Technical Committee approved January 1949.

TABLE 1—*Fifth-Wheel Location and Tabulation Values*

TIRE SIZE	*D*, DISTANCE OF FIFTH WHEEL FORWARD OF REAR AXLE, IN. (NEAREST 1/4 IN.)																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7.50/20	54 1/4	54 3/4	55	55 1/2	56	56 1/2	57	57 3/4	58 1/4	58 3/4	59 1/4	60	60 1/2	61	61 3/4	62 1/4	63
8.25/20	54 1/2	55	55 1/2	56	56 1/2	57	57 1/2	58	58 1/2	59	59 3/4	60 1/4	61	61 1/2	62	62 3/4	63 1/2
9.00/20	56	56 1/4	56 3/4	57 1/4	57 3/4	58 1/4	59	59 1/2	60	60 1/2	61 1/4	61 3/4	62 1/4	63	63 1/2	64 1/4	64 3/4
10.00/20	57	57 1/2	58	58 1/2	59	59 1/2	60	60 1/2	61	61 1/2	62 1/4	62 3/4	63 1/2	64	64 3/4	65 1/4	66
10.00/22	57 1/2	58	58 1/2	59	59 1/2	60	60 1/2	61	61 1/2	62 1/4	62 3/4	63 1/2	64	64 3/4	65 1/4	66	66 1/2
10.00/24	58	58 1/2	59	59 1/2	60	60 1/2	61	61 1/2	62 1/4	62 3/4	63 1/2	64	64 3/4	65 1/4	66	66 1/2	67 1/4
11.00/20	57 1/4	57 3/4	58 1/4	58 3/4	59 1/4	59 3/4	60 1/4	61	61 1/2	62	62 1/2	63 1/4	63 3/4	64 1/2	65	65 3/4	66 1/4
11.00/22	57 3/4	58 1/4	58 3/4	59 1/4	59 3/4	60 1/4	61	61 1/2	62	62 1/2	63 1/4	63 3/4	64 1/2	65	65 3/4	66 1/4	67
11.00/24	58 1/4	58 3/4	59 1/4	59 3/4	60 1/4	61	61 1/2	62	62 1/2	63 1/4	63 3/4	64 1/2	65	65 3/4	66 1/4	67	67 3/4
12.00/20	60 1/4	60 3/4	61 1/4	61 3/4	62 1/4	62 3/4	63 1/4	63 3/4	64 1/4	65	65 1/2	66	66 3/4	67 1/4	67 3/4	68 1/2	69 1/4
12.00/24	61 1/4	61 3/4	62 1/4	62 3/4	63 1/4	63 3/4	64 1/4	65	65 1/2	66	66 3/4	67 1/4	67 3/4	68 1/2	69 1/4	69 3/4	70 1/2

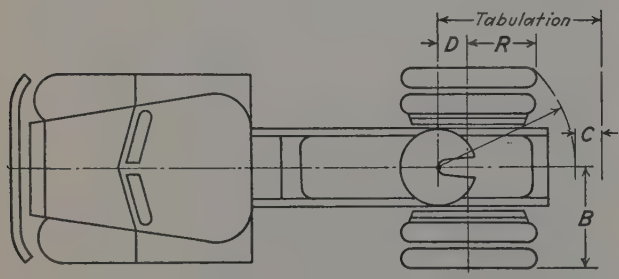


FIG. 1—TRUCK-TRACTOR TRAILER CLEARANCES

$$\text{Tabulation} = \sqrt{(D + R)^2 + B^2} + C \qquad C \text{ min} = 3 \text{ in.}$$

Note—In positioning the fifth wheel in relation to the rear axle, care must be exercised to see that the trailer landing gear (if provided) is located so that there is no danger of the trailer tipping during loading and unloading operations

TABLE 2—*Truck-Tractor Widths Over Tires*

TIRE SIZE	TIRE OD IN.	TIRE RADIUS, *R*, IN.	TRUCK-TRACTOR OVERALL WIDTH, IN.	AVERAGE WIDTH, *B*, IN.
7.50/20	37	18.5	92	46
8.25/20	38.3	19.15	92	46
9.00/20	40.5	20.25	94	47
10.00/20	41.4	20.70	96	48
10.00/22	43.4	21.70	96	48
10.00/24	45.4	22.70	96	48
11.00/20	42.7	21.35	96	48
11.00/22	44.7	22.35	96	48
11.00/24	46.7	23.35	96	48
12.00/20	44.2	22.1	102	51
12.00/24	48.2	24.1	102	51

Propeller-Shaft Midship Mounting

SAE Recommended Practice

Report of Motor Truck Division approved January 1927 and last revised January 1941.

[*This SAE Recommended Practice applies to propeller-shaft midship mountings for motor trucks and motorcoaches.*]

The type of housing shown in Fig. 1 is recommended as a satisfactory design but is not a part of the standard. No slip-joint in the forward section of the shaft is required as clearance is provided in the housing for the bearing and shaft to slide longitudinally. Where a slip-joint is used, the housing should be designed according to requirements. The shafts and bearings recommended are considered adequate for all usual installations. Where heavier duty may require larger bearings, the shaft dimensions should be determined by the manufacturer and the purchaser.

A splined shaft end is optional, and when used, the bearing locknut may be omitted.

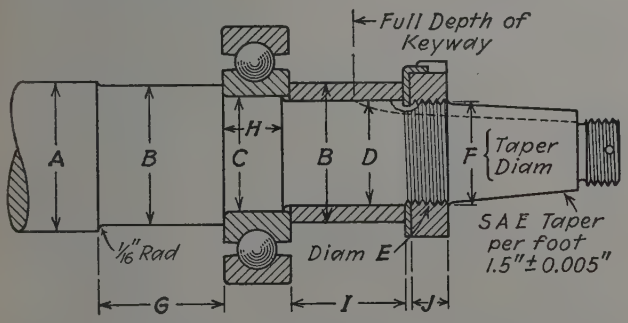


FIG. 1—PROPELLER-SHAFT MIDSHIP MOUNTING

TABLE 1—*Three-Joint Propeller-Shaft Midship Mounting*[a]

Tube diameter, *A*, in.	2	2	2¼	2½	3
B, +0.005, −0 in.	1.6870	1.8750	2.1250	2.3750	2.5620
C, max	1.3780	1.5748	1.7717	1.9685	2.1654
C, min	1.3772	1.5740	1.7709	1.9677	2.1646
D, +0, −0.003 in.	1.3740	1.4990	1.6240	1.8740	2.1240
E	1⅜–18	1½–18	1⅝–16	1⅞–16	2⅛–16
SAE taper shaft end, *F*	1¼	1⅜	1½	1¾	2
G, in.	1⅝	1¾	1⅞	2	2⅛
H, in.	49/64	27/32	59/64	1	1 5/64
I, in.	1 9/16	1 11/16	1 13/16	1 15/16	2 1/16
J, in.	7/16	7/16	9/16	9/16	11/16
Bearing no.	307	308	309	310	311

[a] The oil retainer rings should be adjusted for minimum clearance after the housing and shaft are assembled in the chassis.

Rating of Side-Opening Power Take-Offs

SAE Standard

Report of Transportation and Maintenance Technical Committee approved November 1948.

Using 1500 hr as the average life expectancy of a side-opening power take-off, the manufacturer shall rate the unit in terms of horsepower at 500, 1000, and 1500 rpm of the power-take-off output shaft.

For intermittent service the manufacturer shall rate the unit in terms of maximum torque (in.-lb) at either 500 or 1000 rpm of the power-take-off output shaft.

Fifth-Wheel Kingpin

SAE Standard

Report of Motorcoach and Motor Truck Division approved January 1940.

[This SAE Standard applies to fifth-wheel kingpins for commercial trailers and semi-trailers.]

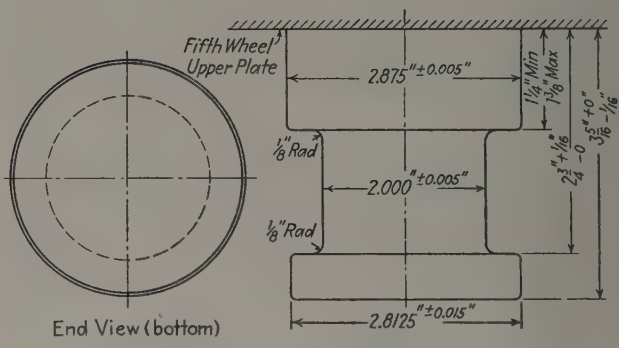


FIG. 1—FIFTH-WHEEL KINGPIN

Semi-Trailer Brake-Connection Locations

SAE Recommended Practice

Report of Motorcoach and Motor Truck Technical Committee approved September 1948.

Manual Type—*Truck-Tractor Fittings*—Fittings for connecting the coupling hose shall be located approximately 3 in. back of the cab and in any convenient location above the frame level. They should preferably be located from 4 to 8 in. on each side of the centerline of the chassis. See Figs. 1 and 2.

Semi-Trailer Fittings—Fittings for connecting the operating hoses shall be located at the forward end of the semi-trailer and approximately 4 to 8 in. on each side of the centerline of the trailer. Air-hose connections should be equipped with hose-coupling set, Fig. 3, and vacuum brakes should have hose-

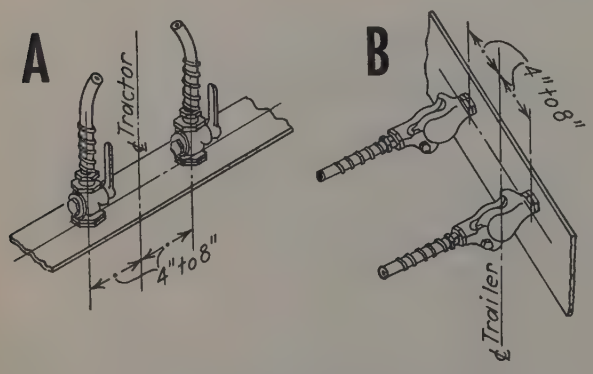


FIG. 1—AIR FITTINGS ON (A) TRUCK TRACTOR AND (B) SEMI-TRAILER

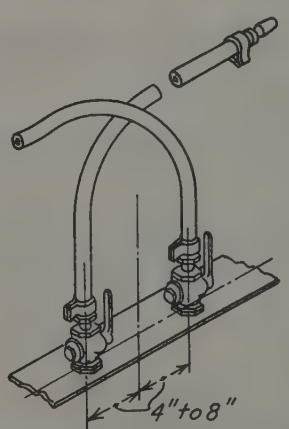


FIG. 2—VACUUM FITTINGS ON TRUCK TRACTOR (VERTICAL POSITION SHOWN, OTHER POSITION OPTIONAL)

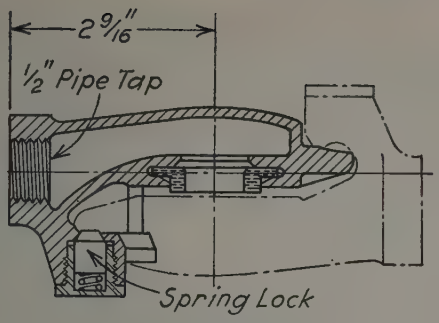


FIG. 3—AIR-HOSE COUPLING

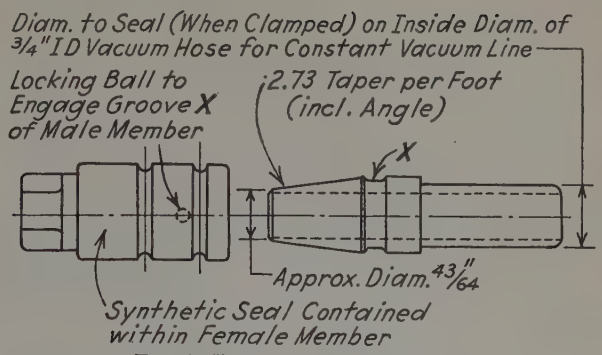

Diam. to Seal (When Clamped) on Inside Diam. of 3/4" I D Vacuum Hose for Constant Vacuum Line
Locking Ball to Engage Groove X of Male Member
2.73 Taper per Foot (incl. Angle)
X
Approx. Diam. 43/64"
Synthetic Seal Contained within Female Member

FIG. 4—VACUUM-HOSE COUPLING

coupling set, Fig. 4, to insure interchangeability between various truck tractors and trailers.

(*Note*—Care should be exercised in calculating hose lengths so that the hose equipment of the truck tractor will be of sufficient length to operate with manual or automatic trailer in the event that center distances of the fittings exceed the 8-in. dimension on either side of the centerline, Fig. 5, of the semi-trailer.)

Semi-Trailer Electrical Connection Location—*Truck-tractor connections* should be mounted on the centerline of the chassis behind the cab, approximately between the hose connections.

Semi-trailer connections should be mounted on the centerline of the trailer at the forward end, approximately between the hose connections.

(*Note*—The location of the electrical connection in line horizontally with the hose connections will permit the operator to strap electrical cable to one or the other of the hose connections to prevent fouling when disconnected.)

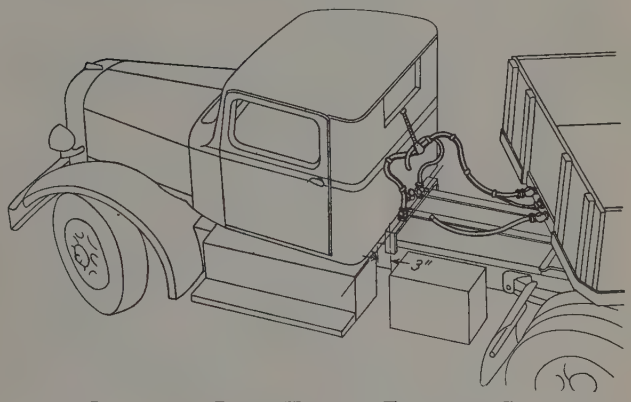


FIG. 5—LOCATION OF BRAKE HOSE AND ELECTRICAL CONNECTIONS

Side-Mounted Gasoline Tanks

SAE Recommended Practice

Report of Motorcoach and Motor Truck Technical Committee approved April 1947 and last revised March 1949.

[*This SAE Recommended Practice applies to side-mounted gasoline tanks on truck tractors.*]

Construction—(*Note*—Some acceptable means of meeting these specifications are given in *italics* immediately following the applicable item. These suggestions are for information only.)

1. Materials used in the construction of the tank and its fittings, the methods or processes of joining metals, the assembly of fittings to the tank, and the threads in fittings shall be suitable for the purpose intended.

(*Except as otherwise specifically provided, joints should be made by arc, gas, seam, or spot welding, brazing or silver soldering.*

Flanges or spuds should be provided for the assembly of all fittings to the tank.

Threads in fittings, except the fill-pipe cap, should be American (National) Standard Taper Pipe Thread or SAE Standard Short

Dryseal Taper Pipe Thread. There should be not less than four full threads in engagement in any fitting.)

2. Drain or other fittings applied to the bottom of the tank shall be designed and applied in such a manner as to guard against their being torn loose and shall permit complete draining. The tank drain shall be of adequate size.

(*Fittings applied to bottom of tank should not extend more than ¾ in. below the lowest part of the tank. Minimum drain plug size should be ⅜-in. pipe thread.*)

3. The fitting through which gasoline is fed or drawn from the tank shall have its exit from the top part of the tank above the full line of the tank.

4. When pressure means are provided to force the flow of gasoline from the gasoline tank, means shall also be provided to prevent continuous flow of gasoline from the tank in the event of a ruptured gasoline feed line.

5. The fill pipe shall be designed and located to minimize the probability of being torn loose. Design of pipe and vents shall permit filling the tank with normal gasoline at the rate of not less than 20 gal per min without spillage.

6. The air intake vent shall be of the nonspill type. It may be mounted separately or combined with the filler cap or safety vent.

(*The air intake vent should be a ball check or equivalent.*)

7. The tank shall be provided with a safety vent or vents which shall limit the rise in pressure in the tank under any fire condition to a maximum of 50 psi. The vent area shall be sufficient to prevent a rise in pressure in the tank with a sustained fire of any magnitude of more than 10% of the release pressure of the safety vent or vents. If one safety vent is furnished, it shall be located at the top of the tank.

(*Safety vents should be of the fusible type.*)

Tank Capacity

8. Liquid capacity of the tank shall be limited to a maximum of not more than 95% of its total volume.

Tank Markings

9. Each tank shall be marked to identify its manufacturer and to indicate the approximate date of its manufacture by date, lot number, or other means.

Installation

10. The tank shall be mounted in accordance with the best commercial practice.

11. The fill pipe shall be outisde the cab or body and must be so located as to minimize the likelihood of spillage of gasoline on the exhaust piping, muffler, or battery during the filling process.

12. Gravity or siphon feed to carburetor shall not be used.

13. The feed line shall not be arranged to draw gasoline from two or more tanks simultaneously. A selector control valve shall be furnished when more than one tank is used. The selector control valve must be installed so that either (a) it is in normal reach of the driver so that he can operate it without taking his eyes from the road or departing from his customary driving position or (b) so that the driver must stop the vehicle and leave his seat to operate the valve.

Tests

14. The tank, when filled with water equal in weight to that of its gasoline capacity, shall withstand without leakage a drop from a clear height of 30 ft, falling so as to strike squarely on one corner on concrete or equal surface. The concrete or equal surface shall not rupture under the impact. The fill pipe and cap, gasoline gage sending device, and the air intake and safety vents shall not leak more than 1 oz per min as a result of this test.

15. The fill pipe and tank must withstand without leakage a drop from a clear height of 10 ft, falling so as to strike squarely on the fill pipe on a concrete or equal surface. The concrete or equal surface shall not rupture under the impact. The tank shall contain water equal in weight to its gasoline capacity during this test. The fill cap shall not leak more than 1 oz per min after this test.

16. Spillage or gasoline leakage shall not be at a rate greater than 1 oz per min with the full tank within 30 deg of inverted position at room temperature. The fill pipe, cap, gasoline gage, air intake vent, and safety vents shall withstand this test. Outlet pipe is to be plugged for the test.

17. The safety vent, or vents, shall limit the rise in internal pressure in the tank to a maximum of 50 psi when the tank is subjected to the following fire conditions.

(a) Tank filled to three quarters of rated capacity with standard gasoline and placed in inverted position, with the gasoline-feed-outlet connection plugged.

(b) An enveloping flame applied to the tank with sufficient intensity to produce an internal gasoline temperature rise of at least 6 F per min starting from a gasoline temperature of 50 to 80 F. This test shall continue until a release in pressure results from operation of the safety vent or vents.

18. The tank, fill-pipe cap (except for destroyed vents), gasoline gage, and air intake vent shall not leak more than 1 oz per min as a result of the test prescribed in item 17.

19. The tank and all appurtenances including fill pipe, cap, gasoline gage, and air intake vent shall withstand an internal hydrostatic pressure without rupture of 150% of the maximum pressure at which the safety vent releases in the fire test.

Spark Arresters for Internal-Combustion Engines

SAE Standard

Report of Tractor Technical Committee approved January 1951.

Scope—This specification covers the efficiency and endurance life of spark arresters used on internal-combustion engines, the purpose being to prevent the emission of flowing carbon particles of a sufficiently large size to ignite combustible material of the nature found in forests, grain fields, and grass fields. It does not cover applications requiring flame arresting, exhaust-gas cooling, and isolation from explosive gases.

Test Procedure—Of necessity and for the sake of uniformity the test procedure requires the use of synthetic particles injected into the exhaust system during the efficiency determination. However, the endurance life shall be determined by actual field performance. The following procedure applies to the laboratory determination of arrester efficiency.

Apparatus—The apparatus shall consist of an internal-combustion engine (coupled to a dynamometer), spark arrester, and positive trap. The arrester shall be mounted as intended to operate on the engine and discharge into the positive trap in the manner shown in Fig. 1. Specifications for the trap are also shown in Fig. 1. It shall be cleaned before each test run.

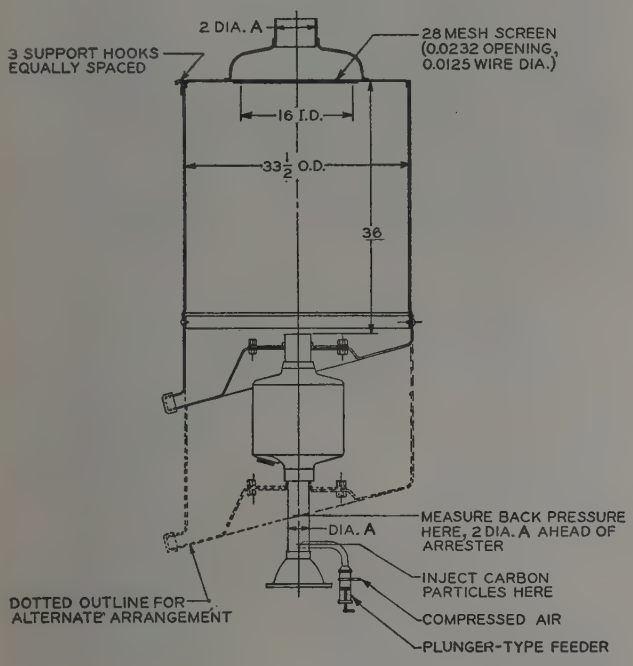


Fig. 1—Spark-Arrester Test Apparatus

Test Samples—The test samples shall be a carbonaceous material known as "Tando" or an equivalent carbonaceous material having a density of 40 lb per cu ft. It shall be graded to the following sizes and desiccated immediately prior to the test. (A variation of ±2% is allowed in grading of the samples.)

Test sample A (hereafter known as small carbon) is that which passes a 14 mesh Tyler screen (0.046 opening, 0.25 diameter wire) and is retained by a 28 mesh Tyler screen (0.0232 opening, 0.0125 diameter wire).

Test sample B (hereafter known as large carbon) is that which passes an 8 mesh Tyler screen (0.093 opening, 0.032 diameter wire) and is retained by a 14 mesh Tyler screen.

Injecting Mechanism—The test samples may be injected by any type of feeder which does not crush or grind the material. It shall be located as shown in Fig. 1.

Engine Loads and Speeds—The test shall be conducted at two engine operating conditions as specified in this Standard in order to insure the acceptability of the arrester over the entire operating range. A sufficient number of tests (a minimum of two) shall be made with each test sample and at each condition of engine operation in order to obtain a reliable average. Engine conditions which influence either the volume or temperature of the exhaust gases, such as load, speed, and water temperature, shall be stabilized before each test by at least 15 min running at the specified test conditions immediately prior to injecting the desiccated test sample.

Details of Test—*Engine Size*—The engine shall be of a proper size for the arrester under test. The spark-arrester manufacturer shall specify the engine size range for which the arrester is suitable.

Installation—Leaks and drain holes shall be closed during test and subsequent operation. Provisions shall be made for measuring the back pressure created by the arrester according to Fig. 1.

Engine Operating Conditions—The arrester shall be tested at the two specified engine operating conditions listed below for each particular application for which approval is desired. Unqualified approval of the arrester requires a successful test for the three applications listed as follows:

Trucks: (a) 80% rated net load at rated speed.
(b) 50% attainable load at one-half rated speed.

Diesel Engine Powered Tractors: (a) 100% rated load at rated speed.
(b) no load at low idle speed.

Gasoline Engine Powered, Tractors: (a) 100% rated load at rated speed.
(b) no load at governed high idle speed.

Other Mobile Equipment: Use load conditions specified for tractors.

A typical engine performance curve is shown in Fig. 2 to illustrate the above specified loading conditions.

Weight of Test Sample—Duplicate tests shall be made with each grade of "Tando" (small carbon and large carbon), each test using the sample weight specified as follows.

1. Engines up to 1000-cu in. displacement—specified minimum of 100 g.

(*Continued on next page.*)

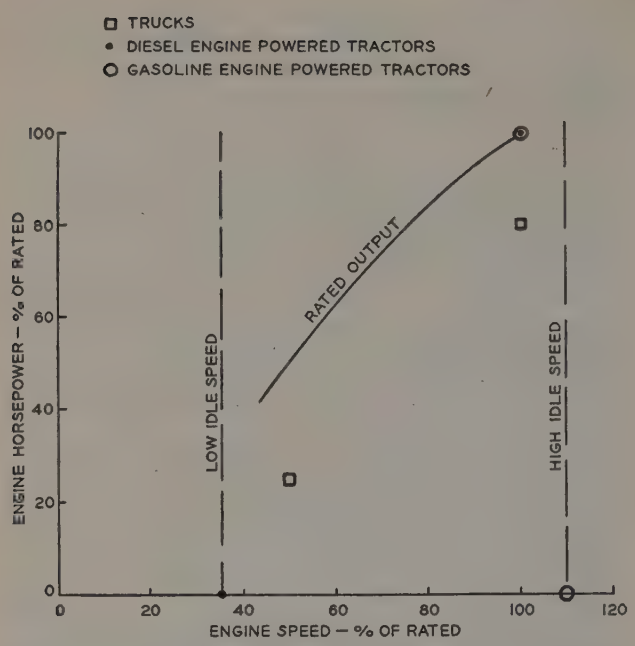


FIG. 2—TYPICAL PERFORMANCE CURVE FOR GASOLINE AND DIESEL ENGINES UNDER LOADING CONDITIONS OF SPARK-ARRESTER TEST

2. Engines above 1000-cu in. displacement—specified minimum increased on a sliding scale according to formula:

$$\text{Weight (grams)} = \frac{\text{Displacement} \times 100}{1000}$$

Duration of Test—The test samples shall be injected into the exhaust gases at a uniform rate, the rate being adjusted to correspond with the time intervals suggested in Table 1.

TABLE 1—*Time Intervals in Minutes for Sample Injection*

ENGINE DISPLACEMENT, CU IN.	INJECTION PERIOD
0–200	20
200–400	15
400–800	10
800 and up	5

The suggested injection periods are further modified by the requirement that the minimum and maximum periods be 5 and 20 min respectively.

Determination of Results—Upon completion of each test run, the contents of the positive trap shall be removed and screened successively on 14 mesh and 28 mesh Tyler screens. The weights shall be measured and recorded as follows:

Weight of large carbon = weight retained on 14 mesh screen.
Weight of small carbon = sum of weights retained on each screen.

The above weights are used to determine the arrester's efficiency.

Examination of each arrester shall be made to determine whether or not the condition of the internal elements can be visually inspected without destroying the usefulness of the arrester.

Qualifications for Approval—Acceptability and approval of the arrester requires the following test results:

Efficiency Requirements

1. Contents of trap shall contain no large carbon.
2. Contents of trap shall contain no small carbon in excess of 10% of the weight of the original sample.
3. The efficiency shall remain equal to the above standards for the periods listed under Service and Life Requirements.

Service and Life Requirements

1. The arrester must be easily cleaned of the accumulated particles (if cleaning is necessary).
2. A minimum endurance life of 1000 hr is acceptable if visual inspection can readily determine the condition of the internal elements of the arrester.
3. A minimum endurance life equal to life of the engine is required if visual inspection of the internal elements is not possible.

Back Pressure Created by Arrester—At no time during the life of the arrester shall it create sufficiently great back pressure to affect adversely the life and performance of the engine. The maximum permissible back pressure is to be specified by the engine manufacturer.

Notes to Designer, User, and Testing Personnel—For best operation of any spark arrester, the outlet should be directed upward. This permits the longest possible cooling period for any glowing particles which might escape the arrester.

It shall be the responsibility of the user to clean the arrester (if necessary) and to replace it as soon as visual inspection denotes deterioration of the internal elements.

The efficiency determination test of any spark arrester will require a minimum of eight test runs. For example, if approval is desired for Diesel-engine-powered tractor applications, the test runs given in Table 2 are necessary.

TABLE 2—*Example Procedure for Diesel-Engine Tractor Applications*

RUN NUMBER	TEST SAMPLE	ENGINE LOADING CONDITION
1	Small carbon	100% rated load at rated speed
2 (repeat of No. 1)		
3	Small carbon	No load at low idle speed
4 (repeat of No. 3)		
5	Large carbon	100% rated load at rated speed
6 (repeat of No. 5)		
7	Large carbon	No load at low idle speed
8 (repeat of No. 7)		

Unqualified approval for all of the applications (listed under Details of Test, Engine Operating Conditions) therefore requires a minimum of 24 test runs.

Tractor Test Code

SAE Recommended Practice

Report of Tractor and Equipment Division approved January 1937 and last revised by Tractor Technical Committee October 1948.

General Instructions—It is suggested that tests be conducted on the tractor to illustrate its performance when used as a source of belt power and also as a draft vehicle. Sufficient data should be observed under specific tests to permit a presentation of belt horsepower and fuel consumption as related to engine speed and also drawbar horsepower and draft in pounds pull for each gear of the vehicle.

Glossary of Terms and Formulas

Time Interval, A = duration of test run in minutes.

Dynamometer Beam Load, L = scale load on dynamometer beam in pounds.

Absorbed Torque, T = L x dynamometer torque-arm constant in ft = torque in lb-ft measured by the dynamometer during belt test.

Belt Pulley Crown Diameter, D = maximum diameter of the tractor driving pulley.

Dynamometer Pulley Crown Diameter, d = maximum diameter of the dynamometer-driven pulley.

Belt Horsepower,

$$BL\text{ Hp} = \frac{Nd \times T}{5252.1}$$

= developed belt horsepower of tractor at a given engine rpm N when driving the dynamometer pulley at Nd rpm.

Per Cent Belt Slip,

$$Sb = 100\left[1 - \frac{Nd\,(d + 1.4w)}{Nbl\,(D + 1.4w)}\right]$$

= slip of flat leather belt of w in. thickness while being driven at an average speed of the tractor pulley of Nlb rpm, and driving dynamometer pulley at Nd rpm.

Correction Factor, f = power-output correction for barometric pressure, atmospheric temperature, or humidity of air. (Refer to the SAE Standard on Engine Test Codes.)

Drawbar Pull, P = average recorded tractor pull in pounds over the test course.

$$\text{Drawbar Horsepower, } Db\text{ Hp} = \frac{P \times V}{375}$$

= horsepower developed by tractor when exerting P lb pull at V mph during test.

Wheel Slip (or Travel Reduction),

$$Sd = 100\left[\frac{Rw - Rwo}{Rw}\right]$$

= per cent slippage of driving wheels or tracks, where Rw is total drive-wheel revolution count to traverse the test course under load and Rwo is drive-wheel revolution count to traverse the same course under no load (as under Driving-Wheel Slippage).

$$\text{Vehicle Traction Coefficient, } C = \frac{P}{W}$$

= ratio of tractor drawbar pull to gross tractor weight W.

Test Conditions—*Limber-Up*—Before recording of test data, it is suggested that each new tractor be given a limber-up run to remove stiffness, to check its condition, and to see that all parts are working normally. Duration of run is optional. It is recommended that each gear be used for some portion of the test.

Adjustments should be made at this time, such as setting valve-tappet clearance and gaps of breaker or spark-plug points, adjusting the clutch, governor, and manifold heat control.

Conduct of Tests—Upon completion of the limber-up run, only adjustments described in literature normally delivered with the equipment are to be made to the tractor, except as required for actual changes of speed and load. Complete recording of all accessories, equipment, weight, and tire, wheel, or lug equipment should be made.

Before recording test data, the tractor should be brought to a condition of stable, sustained operation under conditions of the run. It is imperative that speeds, loads, slippage, cooling-water temperature, air temperature, and temperature of oil to bearings remain substantially constant. Air temperatures shall be taken at a suitable location.

Instrumentation—*Fuel Consumption* shall be determined with scales, flowmeters, or equivalent equipment to an accuracy of plus or minus 1%.

Belt Performance Data are to be recorded by an electric dynamometer, prony brake, or similar power-measuring device coupled through a flat belt with the belt drive of the tractor.

The *Belt Dynamometer* should be properly balanced and calibrated before tests, and belt slippage shall be kept below 1.5%.

Draft Data shall preferably be taken by means of an hydraulic-cylinder instrument, the Gulley traction dynamometer being considered a desirable example of this type. The entire drawbar pull of the tractor under test is to be exerted either directly or by means of a suitable linkage in proportionate amount through the hydraulic cylinder to the trailing load, the pressure developed in the cylinder being transferred to an automatic recording device to present a continuous draft line over periods during which draft data are being secured. An hydraulic diaphragm with recording pressuregraph or strain gauge with recording oscillograph may also be used to record this data.

Engine-Crankshaft Speed is to be recorded by means of a positively driven counting mechanism of mechanical or electrical interruption design.

Drive-Wheel Revolutions shall be recorded by a counting mechanism of mechanical or electrical interruption design, actuated through positive drive from all drive wheels. (An engine revolution counter may be used for this purpose if no slippage is possible between the crankshaft and drive wheels.)

Testing Course—The testing course for drawbar work shall be a level, well-drained surface. It is recommended that the test runway shall be not less than 500 ft long in a straight course over which the data are to be taken. A reasonable length of approach should be maintained leading to the test runway to permit stabilization of test conditions before recording as specified in Conduct of Tests. (Test data for comparative purposes shall not be taken when track condition due to moisture content, dust,

frost, or other conditions is such that reliable or reproducible data cannot be secured.)

Driving-Wheel Slippage—Tractor driving-wheel slippage shall be determined by relation of total wheel-revolution count (as under Instrumentation) under no load and under load in the same gear. The tractor driving-wheel count with no load is to be obtained in each gear with no drawbar load and with engine throttled down to its lowest definitely uniform running performance (to avoid any erratic slippage of lugs which may result from erratic engine operation or forward creep due to inertia effects) over the entire test runway. The tractor driving-wheel count under load is to be recorded during normal draft performance runs over the same length of runway. Wheel weight should be installed for the no-load run the same as for the run under load.

Agricultural Tractor Drawbars

SAE Standard

Report of Agricultural Power Equipment Division approved July 1923 and last revised by Tractor Technical Committee January 1946. This Standard conforms with a corresponding standard published by the American Society of Agricultural Engineers.

[*Fig. 1 and the recommendations contained in the paragraphs referring to the figure are intended to simplify the problem of connecting the power take-off of a driven machine to that of a tractor. When these recommendations are incorporated in the design of power take-off drives, any power take-off driven machine can be quickly connected to any make of tractor without the necessity of supplying special equipment.*]

The diameter of the hitch hole at the end of the tractor drawbar shall be not less than $1\frac{3}{16}$ in.; and in addition, an $1\frac{1}{16}$ in. hole shall be provided in the drawbar 4 in. ahead of the hitch hole. The material in the tractor drawbar shall clear an implement clevis (3 in. wide and having a 3 in. throat clearance) through a 90 deg swing right or left of the tractor-drawbar center line. The tractor drawbar shall be strong enough to carry a 500 lb vertical load at the hitch point.

The horizontal distance *B* (Fig. 1) between the hitch point on the tractor drawbar and the rear-most point on the standard size rubber tire, steel wheel rim lug, or fender of the tractor shall be not less than 4 in.

The vertical distance *C* from the ground line to the top of the drawbar at the hitch point shall be from 12 in. to 15 in., the 15 in. distance being the recommended dimension.

The horizontal distance *A* between the hitch point on the tractor drawbar and the end of the splined shaft of the power take-off shall be 14 in., and the hitch point shall be directly in line with the centerline of the power take-off shaft.

The vertical distance *D* between the top of the drawbar at the hitch point and the centerline of the power take-off splined shaft shall be not less than 6 in. nor more than 15 in., 8 in. being the recommended dimension.

The location of the tractor power take-off shaft shall be within the limits of 3 in. to the right or left of the center line of the tractor. The center line of the power take-off shaft is the recommended location. The weight imposed by the drawn machine or implement on the tractor drawbar at the hitch point shall not exceed 500 lb.

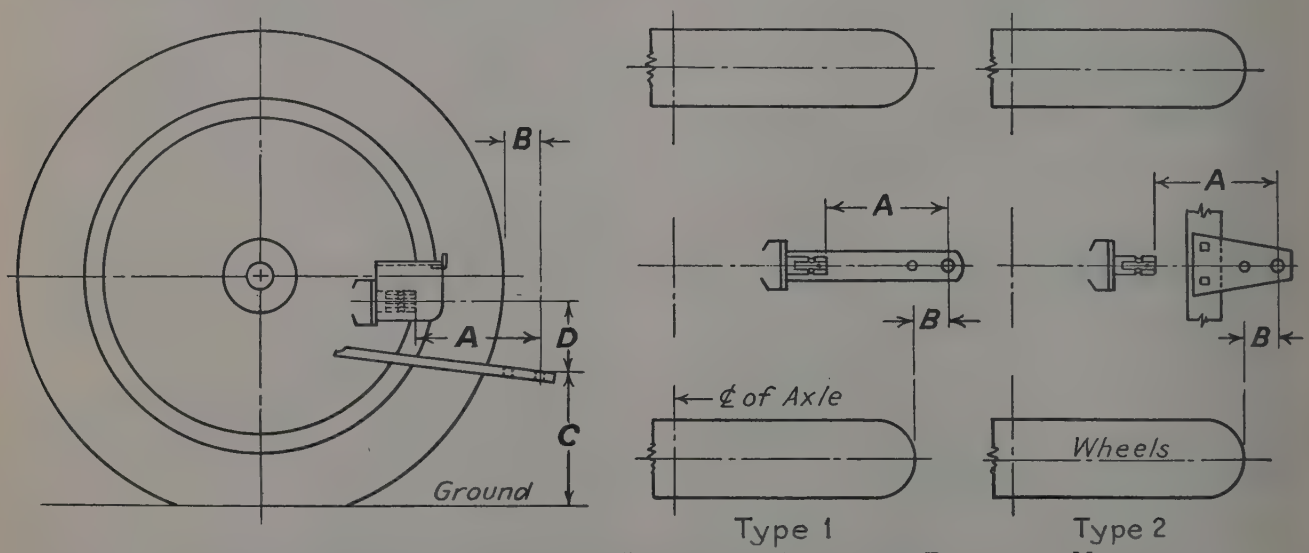


Fig. 1—Power Take-Off and Drawbar Hitch Locations for Agricultural Tractors and Machines

Tractor and Implement Disc Wheels

SAE Recommended Practice

Report of Tractor Technical Committee approved January 1949 and last revised March 1950.

Included in this recommendation are:

1. Wheel diameter of 16 in. with 2¼-in. offset, in two weights and three rim sizes—a total of four combinations.
2. Wheel diameter of 16 in. with 1⅛-in. offset, in two weights and four rim sizes—a total of five combinations.
3. Wheel diameter of 15 in. with 1⅛-in. offset, in one weight and one rim size—one combination.
4. Wheel diameter of 12 in. with 1¼-in. offset, in one weight and one rim size—one combination, to take 5.00 x 12, 2-ply or 4.00 x 12, 4-ply tires.

Table 1 gives rim size, maximum tire size, and maximum load for 16-, 15-, and 12-in. diameter wheels.

Features Common to 15- and 16-In. Diameter Wheels—Discs are designed for reversible mounting on hub. The maximum diameter of the hub pilot is 4.625 in. (reference dimension).

Six holes for ½-in. hub-attaching bolts, 90 deg countersunk on both sides for reversibility, are provided. (These holes will accommodate a cone-head capscrew or stud with cone nut.)

The attaching bolt-circle diameter is 6.005–5.995 in. The maximum diameter of the hub flange is 7¼ in. (reference dimension).

Disc is stamped "L" or "H", indicating light or heavy series, in vicinity of the valve hole, with letters of a minimum height of ⅜ in. Embossing of disc for "L" or "H" stamp is optional. Discs will not carry implement manufacturer's stamped brand.

Interchangeability is provided between 15- and 16-in. agricultural implement wheels and tractor wheels.

16-In. Diameter, 2¼-In. Convex Offset Disc Wheels—The 16-in. diameter, 2¼-in. offset wheel, with valve opening in rim toward convex side, is provided with six clearance holes for

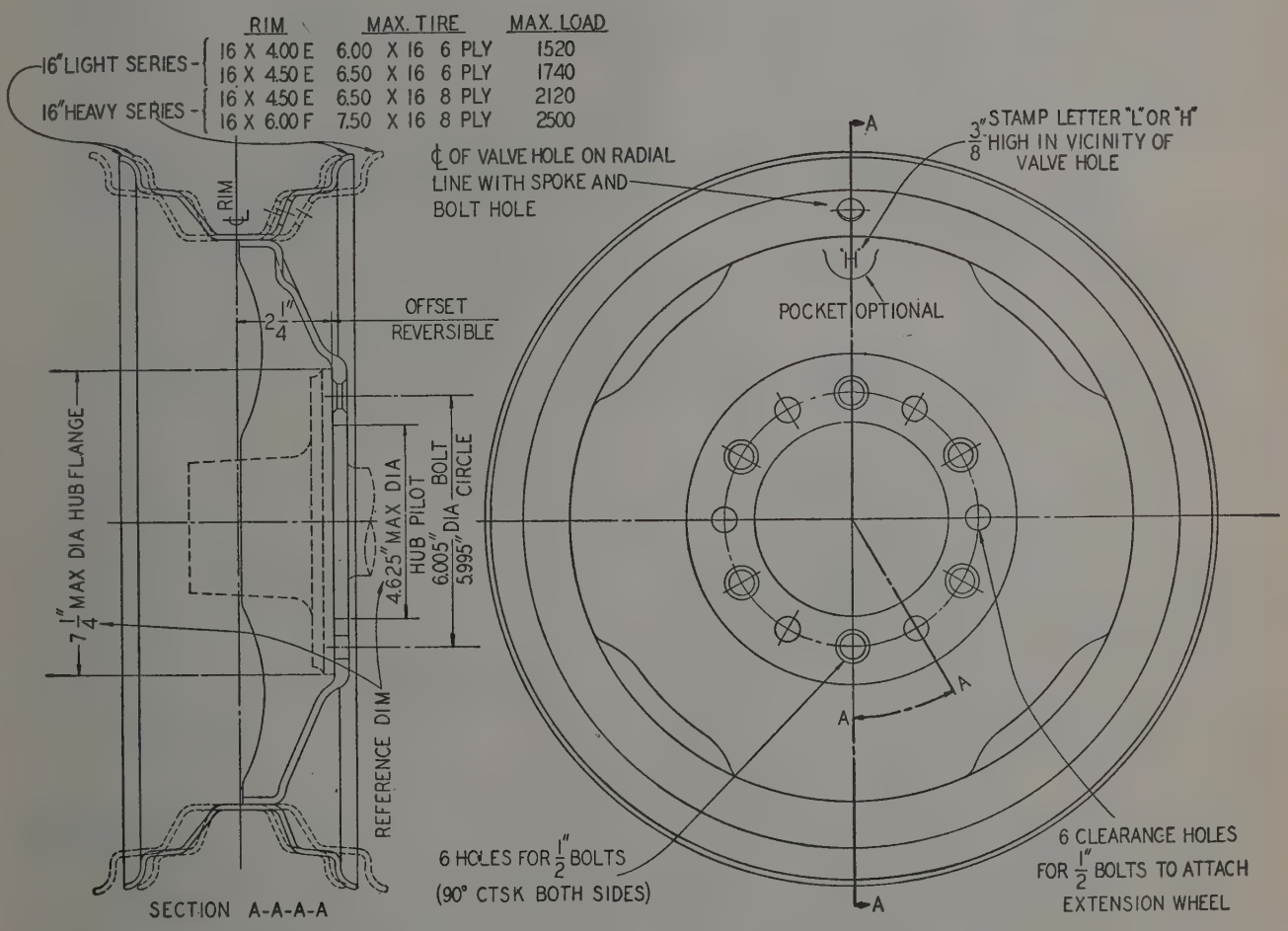

RIM
MAX. TIRE
MAX. LOAD
16" LIGHT SERIES
16 X 4.00 E 6.00 X 16 6 PLY 1520
16 X 4.50 E 6.50 X 16 6 PLY 1740
16" HEAVY SERIES
16 X 4.50 E 6.50 X 16 8 PLY 2120
16 X 6.00 F 7.50 X 16 8 PLY 2500
℄ OF VALVE HOLE ON RADIAL LINE WITH SPOKE AND BOLT HOLE
⅜" STAMP LETTER "L" OR "H" HIGH IN VICINITY OF VALVE HOLE
POCKET OPTIONAL
OFFSET REVERSIBLE
2¼"
7¼" MAX DIA HUB FLANGE
4.625" MAX DIA HUB PILOT
6.005" 5.995" BOLT DIA CIRCLE
REFERENCE DIM
6 HOLES FOR ½" BOLTS (90° CTSK BOTH SIDES)
6 CLEARANCE HOLES FOR ½" BOLTS TO ATTACH EXTENSION WHEEL
SECTION A-A-A-A

FIG. 1—16-IN. DIAMETER, 2¼-IN. OFFSET DISC WHEEL

TABLE 1—*Rim Size, Tire Size, and Load for Tractor and Implement Disc Wheels*

DIAMETER, IN.	OFFSET, IN.	SERIES	RIM SIZE	MAXIMUM TIRE SIZE	MAXIMUM LOAD, LB
16	2¼	Light(L)	16 x 4.00E	6.00 x 16, 6-ply	1520
			16 x 4.50E	6.50 x 16, 6-ply	1740
16	2¼	Heavy(H)	16 x 4.50E	6.50 x 16, 8-ply	2120
			16 x 6.00F	7.50 x 16, 8-ply	2500
16	1⅛	Light(L)	16 x 4.00E	6.00 x 16, 6-ply	1520
			16 x 4.50E	6.50 x 16, 6-ply	1740
16	1⅛	Heavy(H)	16 x 4.50E	6.50 x 16, 8-ply	2120
			16 x 5.50F	7.50 x 16, 8-ply	2500
			16 x 6.00F	7.50 x 16, 8-ply	2500
15	1⅛	Light(L)	15 x 3.00D	5.00 x 15, 4-ply	910
12	1¼	Light(L)	12 x 3.00D	4.00 x 12, 4-ply	635

½-in. bolts to attach extension wheel. These holes are on the same bolt circle and equally spaced between the countersunk hub-attaching bolt holes as shown in Fig. 1.

The valve hole, the disc spoke, the "L" or "H" identification stamp, and one of the countersunk holes for hub-attaching bolts are on a common radial centerline.

16-In. Diameter, 1⅛-In. Convex Offset Disc Wheel—The 16-in. diameter, 1⅛-in. offset disc is provided with four holes for ½-in. carriage bolts for attaching wheel weights. These holes are located in embossments in a plane at 90 deg to axle centerline and are equally spaced on a 10½-in. diameter circle.

The valve opens in rim toward the convex side. The valve hole is located midway between two of the weight holes. One weight hole is on common radial centerline with hub-attaching bolt hole as shown in Fig. 2.

No fixed axial relation is required between the embossments for the weight-attaching bolts and the rim centerline or disc offset.

15-In. Diameter, 1⅛-In. Convex Offset Disc Wheels—The 15-in. diameter, 1⅛-in. offset disc is provided with four holes

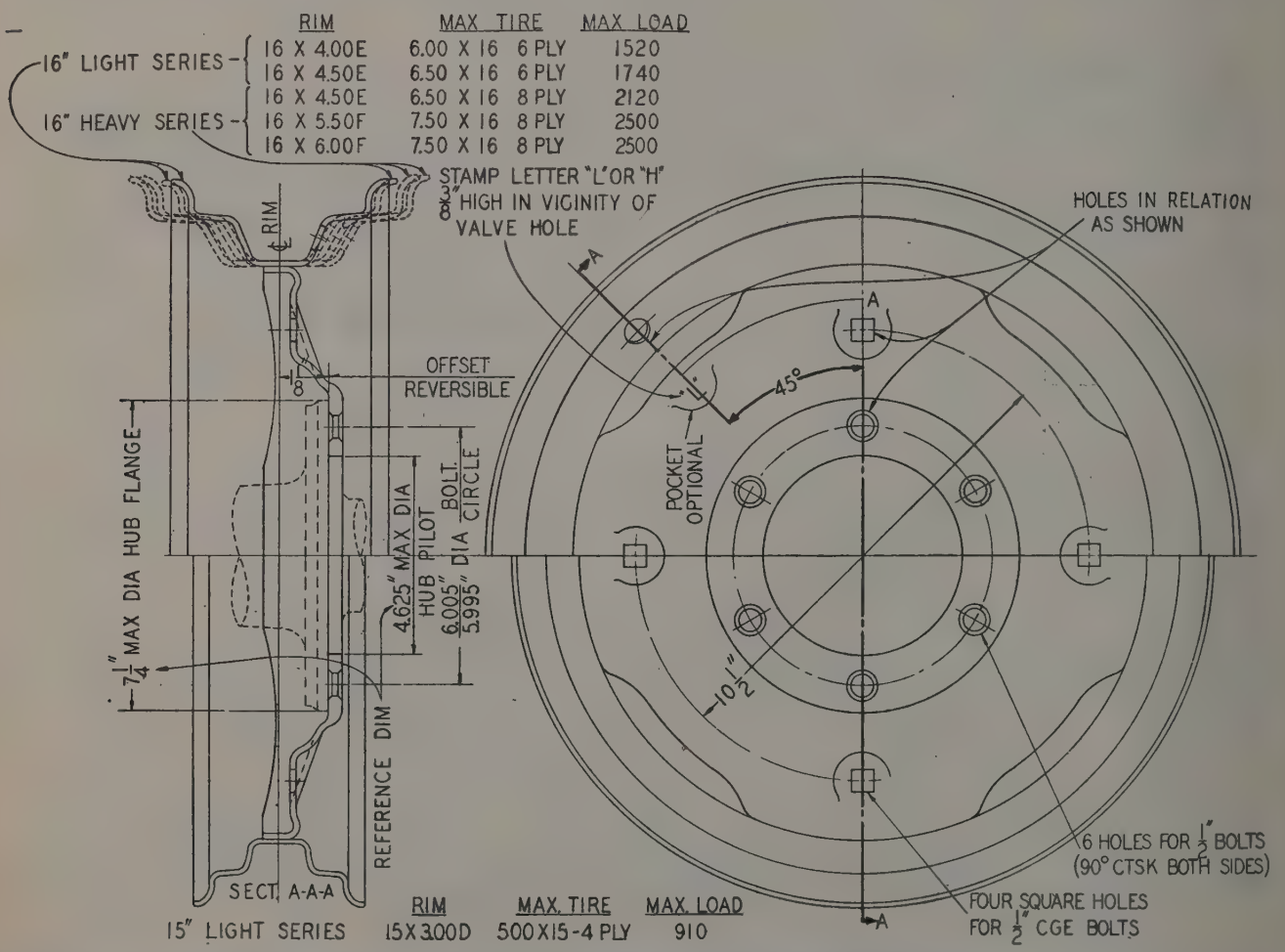


FIG. 2—15-IN. AND 16-IN. DIAMETER, 1⅛-IN. OFFSET DISC WHEELS

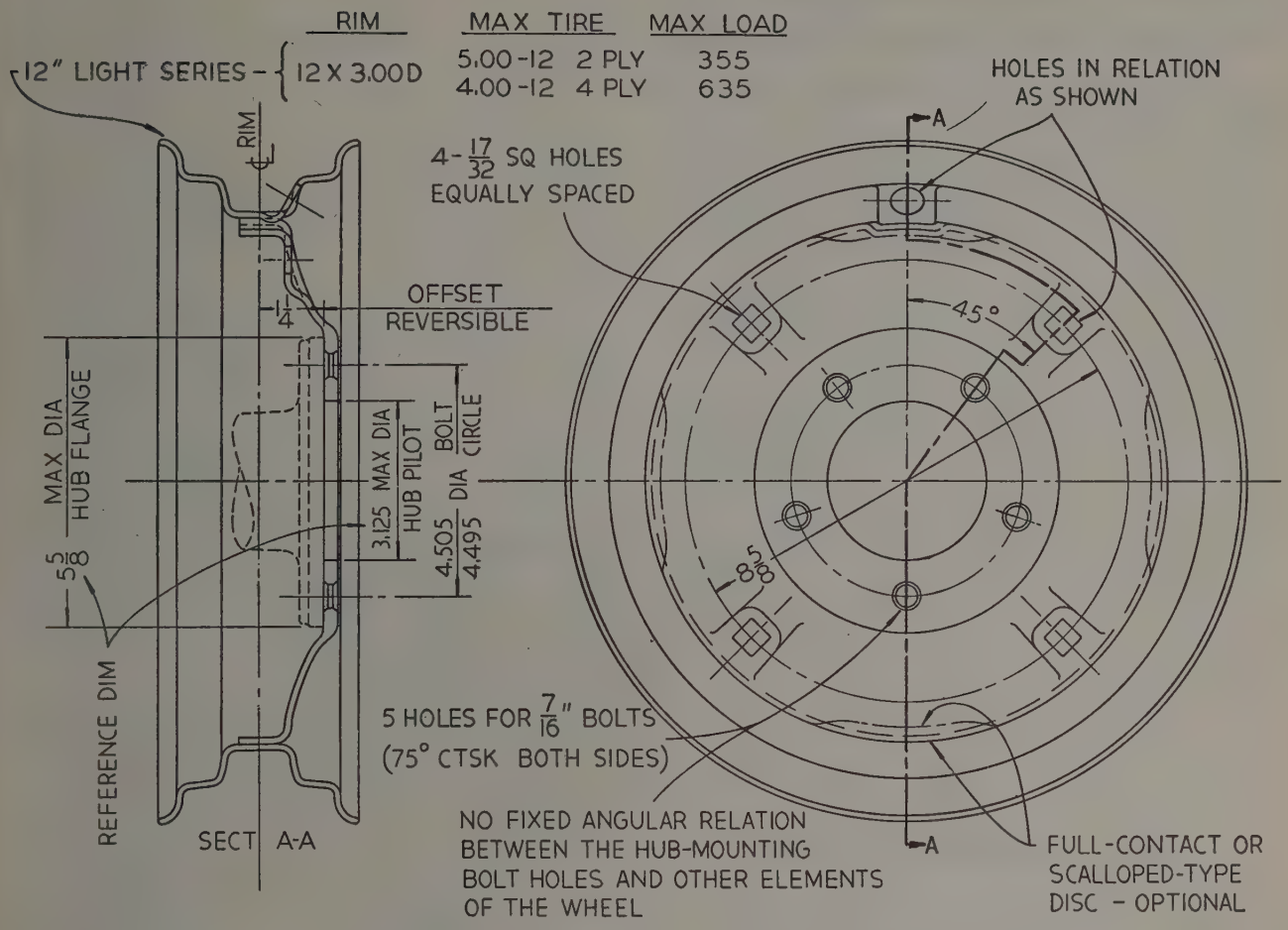


FIG. 3—12-IN. DIAMETER, 1¼-IN. OFFSET DISC WHEEL

for ½-in. carriage bolts for attaching wheel weights. These holes are located in embossments in a plane at 90 deg to axle centerline and are equally spaced on a 10½-in. diameter circle.

The valve hole opens in rim toward the convex side. The valve hole is located midway between two of the weight holes. One weight hole is on common radial centerline with hub-attaching bolt hole as shown in Fig. 2.

No fixed axial relation is required between the embossments for the weight-attaching bolts and the rim centerline or disc offset.

Features standardized in the 15-in. disc design permit use of common wheel weights for both the 15- and 16-in. disc wheels with 1⅛-in. offset.

12-In. Diameter, 1¼-In. Offset Disc Wheels—The disc is designed for reversible mounting. The maximum diameter of hub pilot is 3.125 in. (reference dimension).

Five holes for 7/16-in. hub-attaching bolts, 75 deg countersunk on both sides for reversibility, are provided. (These holes will accommodate a cone-head capscrew or stud with cone nut.)

The attaching bolt-circle diameter is 4.505–4.495 in. The maximum diameter of the hub flange is 5⅝ in. (reference dimension).

The disc is provided with four holes for ½-in. carriage bolts for attaching wheel weights. These holes are located in embossments in a plane at 90 deg to axle centerline and are equally spaced on an 8⅝-in. diameter circle.

The valve hole is located midway between two of the weight holes and opens toward the convex side of the disc as shown in Fig. 3.

No fixed axial relation is required between the embossments for the weight-attaching bolts and the rim centerline or disc offset.

Disc will not carry implement manufacturer's stamped brand.

Hydraulic Remote-Control Farm Tractors and Trailing Farm Implements

SAE Standard

Report of Tractor Technical Committee approved January 1949. This Standard conforms with a corresponding standard published by the American Society of Agricultural Engineers.

Purpose—The purpose of this standard is to establish common mounting and clearance dimensions for hydraulic remote-control cylinders and trailing-type farm implements, with such other specifications as are necessary to accomplish the following objectives:

Permit use of any make or model of trailing-type farm implement adapted to hydraulic remote control with the cylinder furnished with any make or model farm tractor up to and including a maximum of 35 drawbar horsepower.

Eliminate the necessity for supplemental hose lengths or piping for certain types of implements, which will facilitate changing the cylinder from one implement to another and reduce the possibility of introducing dirt or foreign material into the hydraulic system.

Standard Dimensions and Specifications—The hydraulic cylinder with hose shall be considered as part of the tractor hydraulic remote control and shall be built to standard dimensions. Both single- and double-acting cylinders shall operate to raise the implements (or deangle disc harrows) on their extending stroke. Implements requiring actuating force in both directions should be operated by a double-acting cylinder.

Variable-stroke control shall be incorporated in the cylinder or hydraulic system and applied on the retracting stroke. Variable-stroke control is considered necessary in the application of hydraulic control to some implements. Because of forces involved, the use of stroke control or adjustable stops on implements is not recommended.

Cylinder length of stroke shall be 8 in., plus ⅛, minus 0.

Distance, center to center between attaching pins, extended shall be 28¼ in., plus ⅛, minus 0. Cylinder attaching pins shall be 1 in. nominal diameter, with maximum oversize tolerance of 0.005 in. Implement mountings shall provide operating clearance for 1.005 in. maximum diameter pins.

Yokes shall be used on anchor and rod ends.

Width of throat shall be 1 1/16 in. minimum.

Depth of Throat—This shall be as shown in Figs. 1 and 2. The anchor end of the cylinder shall provide clearance as shown in Fig. 1. This affords clearance for a 1 x 2½-in. bar through 30 deg included angle, equally divided, and a 1 x 3-in. bar in perpendicular position. The rod end of the cylinder shall provide clearance as shown in Fig. 2. This affords clearance for a 1 x 2½-in. bar through 60 deg. included angle, equally divided, and a 1 x 3-in. bar in perpendicular position.

Clearance Area on Implements—Hydraulic cylinders shall op-

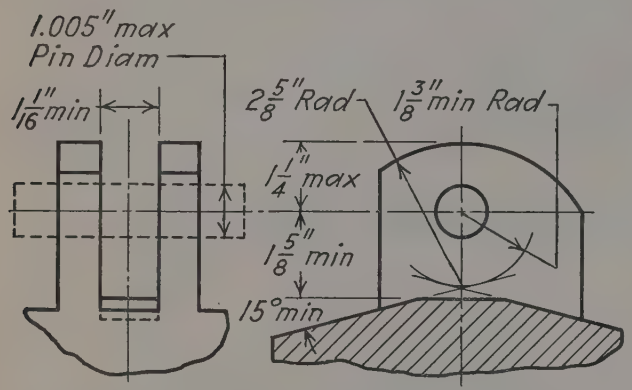


Fig. 1—Yoke Clearances, Anchor End

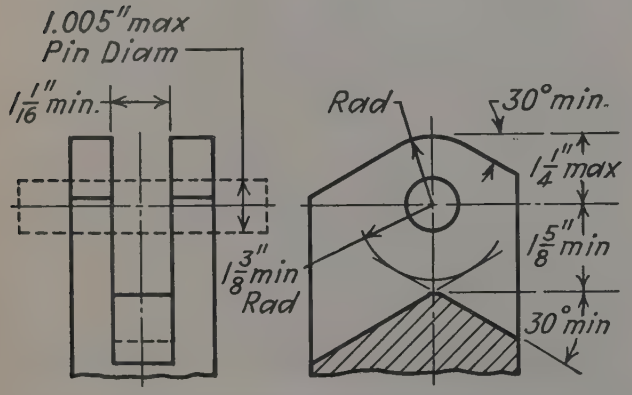


Fig. 2—Yoke Clearances, Rod End

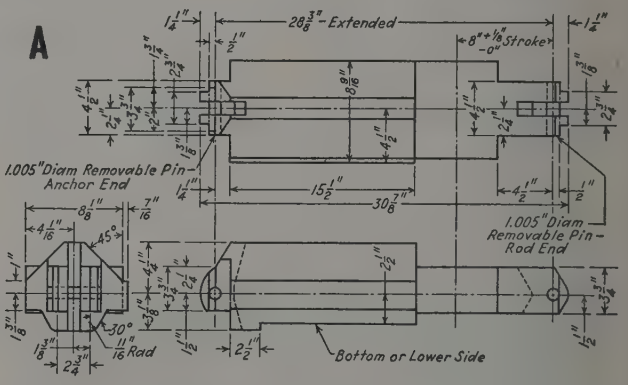


Fig. 3—Clearance Models, Agricultural Hydraulic Cylinders

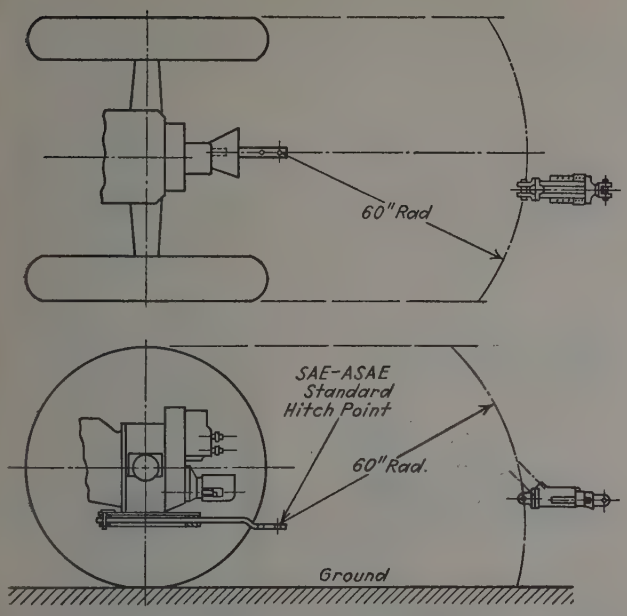


FIG. 4—STANDARD HOSE LENGTHS

erate within the composite volume specified in Figs. 3a and 3b. Implements designed for remote cylinder operation shall provide clearance for a cylinder of the composite volume specified in Figs. 3a and 3b.

Standard Hose Length—Tractor manufacturers shall provide sufficient length of hose so that the cylinder is operable when the front anchor pin is located at a 60-in. maximum spherical radius whose center is the SAE-ASAE Standard drawbar hitch point (Fig. 4).

The implement manufacturer must locate the cylinder on the implement to provide allowances for cushion-spring hitches, maneuverability, and turning so that the implement can be operated safely without stretching or breaking the hose under any circumstances.

Hose Supports and Connections to Cylinders—Support required for remote cylinder hose shall be considered as part of the implement. Hose connections shall be such that the hose will not interfere with bars extending through the yoke on either end of the cylinder.

Operating Time at Rated Engine Speed—Operating time 1½ to 2 sec per 8-in. stroke at rated hydraulic pressure. Provision is to be made on the implement to accommodate the full stroke of the cylinder.

Agricultural Tractor Power Take-Off

SAE Standard

Report of Agricultural Power Equipment Division approved July 1923 and last revised by Tractor Technical Committee January 1946. This Standard conforms with a corresponding standard published by the American Society of Agricultural Engineers.

[*By general understanding the standardizing activities of the SAE in the agricultural engineering field are primarily concerned with the power-supplying units, while those of the ASAE are primarily concerned with the units using power and the application of the power. This standard therefore lies in both fields of interest.*]

The agricultural tractor power take-off shaft (except belt-pulley shafts) for all types of power take-off drives issuing from the tractor in any direction shall have the spline dimensions shown in Table 1 and a minimum clearance of 3¼ in. between the end of the spline shaft and any stationary part of the tractor, this clearance to be the spherical radius from the center of the spline shaft end. (See Tables 1 and 2 and Fig. 1.)

The spline shaft groove is provided for use where additional retaining means is desired. The normal speed of the power take-off shaft shall be 536 rpm, ±10 rpm, the direction of rotation to be clockwise when facing in the direction of forward travel. (This applies only to fore-and-aft power take-off shafts.)

The tractor shall be equipped with a power take-off master

TABLE 1—*Shaft and Hub Spline Dimensions (See Fig. 1)*

A, Nominal Diameter	Spline on Shaft						Spline on Hub					
	D, Large Diameter		d, Small Diameter		W, Spline Width		D_1, Large Diameter		d_1, Small Diameter		W_1, Spline Width	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1⅜	1.373	1.371	1.108	1.098	0.340	0.338	1.375	1.374	1.170	1.168	0.344	0.342
1¾	1.747	1.745	1.427	1.417	0.433	0.431	1.750	1.749	1.489	1.487	0.438	0.436

TABLE 2—*General Shaft and Hub Dimensions (See Fig. 1)*

A, Shaft Diameter	Shaft						Hub
	E, Pin-Hole Diameter	Pin Diameter	B, Chamfer Length	G, Side Radius	F, Groove-Bottom Diameter		E, Pin-Hole Diameter
					Max	Min	
1⅜	21/64 (0.328)	5/16	9/32	17/64	1.160	1.155	21/64 (0.328)
1¾	25/64 (0.390)	3/8	11/32	21/64	1.470	1.465	25/64 (0.390)

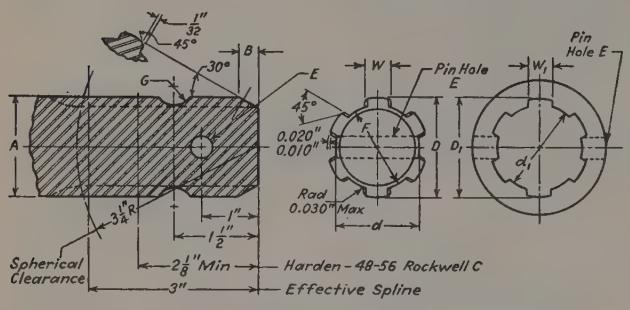


FIG. 1—AGRICULTURAL TRACTOR POWER TAKE-OFF SPLINE

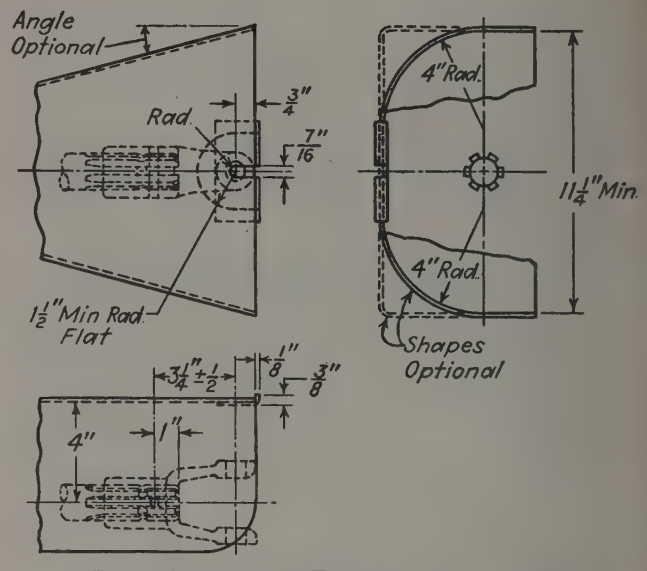


FIG. 2—AGRICULTURAL TRACTOR POWER TAKE-OFF MASTER SHIELD

shield (Fig. 2) incorporating the attaching point for the shield of the driven machine as dimensioned. The strength of the master shield shall be sufficient to support the weight of the operator without taking a permanent set. The manufacturer of the driven machine shall provide adequate shielding for that part of the power line drive which he furnishes and which shall be attachable to the standard power-shaft master shield of the tractor.

Tractor Belt Speeds and Pulley Width

SAE Standard

Report of Tractor Division approved August 1917 and last revised January 1944.

The standard belt speed for agricultural tractors shall be 3100 fpm plus or minus 100 fpm. The minimum width of agricultural tractor belt pulleys shall be such as to provide for the use of a belt 6 in. in width.

Grader Cutting Edge

SAE Standard

Report of Construction and Industrial Machinery Technical Committee approved January 1951.

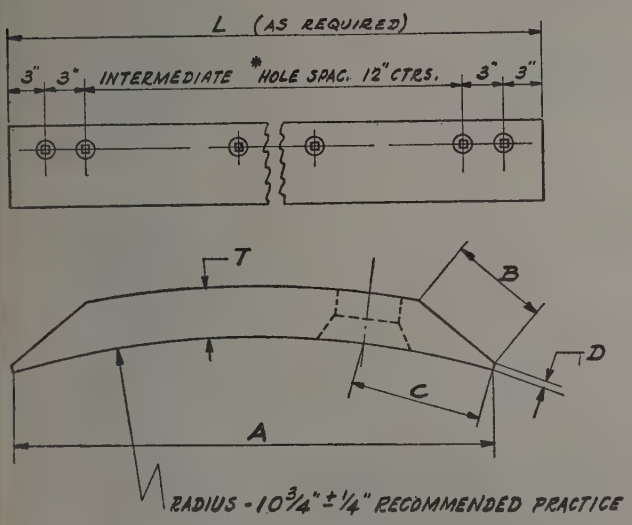


TABLE 1—*Nominal Dimensions of Grader Cutting Edge*

THICKNESS, *T*, IN.	*A*	*B*	*C*	*D*
1/2	6	1 1/8	1 5/8	3/32
1/2	8	1 1/8	1 5/8	3/32
5/8	6	1 5/16	1 5/8	3/32
5/8	8	1 5/16	1 5/8	3/32

FIG. 1—GRADER CUTTING EDGE

* Optional intermediate hole spacing 6 in. centers for heavy-duty application

Use countersunk 11/16-in. square holes for 5/8-in. No. 3 head plow bolts

Bulldozer Cutting Edge

SAE Standard

Report of Construction and Industrial Machinery Technical Committee approved January 1951.

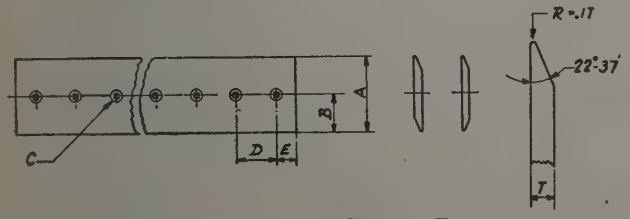


FIG. 1—BULLDOZER CUTTING EDGE

TABLE 1—*Nominal Dimensions of Bulldozer Cutting Edge*

Width, *A*, in.	6	8	10
Edge Width, *B*, in.	3	4	5
Bolt Size[a], *C*, in.	3/4	3/4	7/8
Hole Spacing, *D*, in.	6	6	6
End Distance, *E*, in.	$3^{+0}_{-1/8}$	$3^{+0}_{-1/8}$	$3^{+0}_{-1/8}$

[a] Plow Bolt No. 3 head. See American Standard Plow Bolts, ASA B18.9—1950. Physical requirements of bolt shall conform to Grade 5 of SAE Recommended Practice for Physical Requirements for Bolts, Capscrews, Studs, and Nuts.

Yardage Ratings

SAE Standard

Report of Construction and Industrial Machinery Technical Committee approved December 1948.

[*Conversion of yardage ratings into capacity in terms of pay yards is considered to be the province of the contractor and engineer for each specific project.*]

Carry-Type Scrapers—Capacities shall be rated on the basis of cubic yards. Standard ratings shall include *both struck and heaped capacities.*

Struck capacity of a scraper shall be determined by the product of the area of one side plate contacted by the load multiplied by the width between side plates. (Most scrapers have straight, parallel side plates and flat bottoms, and allowance shall be made for appreciable departure from such construction.) The struck capacity shall be given to the nearest 0.1 cu yd.

When the top of the front apron, in the closed position, is below the top edge of the side plates, the capacity shall be limited either by planes following the contour of the side plates or by a plane at a slope of one vertical to one horizontal, whichever gives the smaller capacity.

To determine the one to one slope for the limiting plane, the scraper shall be set in its normal carrying position with the apron closed.

Mechanisms which are not a part of the side plates but which are adjacent to them and will retain additional load shall be included in the determination of struck capacity. An extension of the ejector or a rear plate above the side plates shall not be included in the determination of struck capacity.

The volume occupied by apron arms, sheave frames, or other internal projections shall not be deducted from the struck capacity.

Heaped capacity of a scraper shall be the volume enclosed by the bowl and apron and four planes at a slope of one vertical to one horizontal, extending upward and inward from the top of the front apron, from the top of the ejector or rear plate and from the top edges of the side plates. For scrapers of less than 12 cu yd struck capacity, the heaped capacity shall be given to the nearest ½ cu yd; for scrapers of 12 cu yd struck capacity and larger, the heaped capacity shall be given to the nearest whole cubic yard.

To determine the one to one slope for limiting planes, the scraper shall be set in its normal carrying position with the apron closed.

If the top edge of the side plate (or extension thereof), front apron, or ejector is not a straight line, a mean line through its configuration may be used to establish the side planes of the heaped capacity.

The possible interference of overhead structures such as sheave guides and cables with the heaped capacity shall be ignored.

Both the struck and heaped capacities as defined are, with minor reservations, definitely measurable quantities which delimit the probable loading characteristics of the vehicle.

Truck and Wagon Bodies—Capacities shall be rated on the basis of cubic yards. Standard ratings shall include *both struck and heaped capacities.*

Struck capacity of a truck or wagon body shall be the actual volume enclosed by the body, struck off by a straight line passed along the top edge of the side plates. The struck capacity shall be given to the nearest 0.1 cu yd.

For bodies with one end open, the capacity at such end shall be limited by a plane passing through the edge of the bottom plate at a slope of one vertical to one horizontal.

Extension of end plates above the sides shall not be included in the struck capacity.

Heaped capacity of a truck or wagon body shall be the volume enclosed by the body and by four planes at a slope of one vertical to one horizontal, extending upward and inward from the top edges of the side and end plates. For bodies of less than 12 cu yd struck capacity, the heaped capacity shall be given to the nearest ½ cu yd; for bodies of 12 cu yd struck capacity and larger, the heaped capacity shall be given to the nearest whole cubic yard.

For bodies with one end open, the heaped capacity at such end shall be limited by a continuation of the plane limiting the struck capacity.

If the top edge of a side or end plate is not a straight line, a mean line through its configuration may be used to establish the sloping top plane of the heaped capacity.

Both the struck and heaped capacities as defined are, with minor reservations, definitely measurable quantities which delimit the probable loading characteristics of the vehicle.

Industrial (Track-Type) Tractor Drawbars

SAE Standard

Report of Construction and Industrial Machinery Technical Committee approved December 1947 and last revised July 1950.

[This Standard includes only those features which will affect the attaching of towed implements. As much freedom of design as possible for such features as overall jaw height, pin length and locking devices, swing angle, and method of locking the bar is left to the tractor manufacturer.]

TABLE 1—*Dimensions for Industrial Tractor Drawbars* (*See Fig. 1*)

TRACTOR SIZE		DRAWBAR HP	*A*	*B*	MIN *C*	MAX RADIUS, *D*	MIN *E*	*F*
Class	Group							
I	1	0–25	1⅛	2½	2¼	2	4	12–15
	2	26–35	1⅜	2½	2¼	2	4	12–15
	3	36–50	1⅜	2½	2¼	2	4	12–15
II	1	51–75	1¾	3½	3¼	3	6	14–18
	2	76–100	1¾	3½	3¼	3	6	14–18
	3	101–125	1¾	3½	3¼	3	6	14–18
III		126–175	2	3¾	4	3½	8	16–21

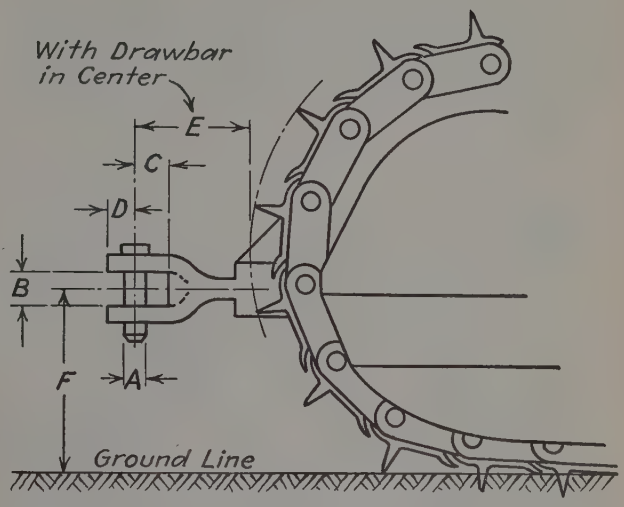


FIG. 1—DIMENSIONS FOR INDUSTRIAL TRACTOR DRAWBARS

Rear Power Take-Off and Mounting Face for Industrial (Track-Type) Tractors

SAE Standard

Report of Construction and Industrial Machinery Technical Committee approved January 1949 and last revised January 1951.

This Standard is intended primarily for tractors (track-type) designated for industrial uses, and it includes those features covering the mounting and driving of equipment such as cable power-control units, heavy-duty winches, bulldozers, hydraulic units, and separate hydraulic pumps. The intent is to standardize mounting facilities and drive connections with the least possible interference with freedom of design.

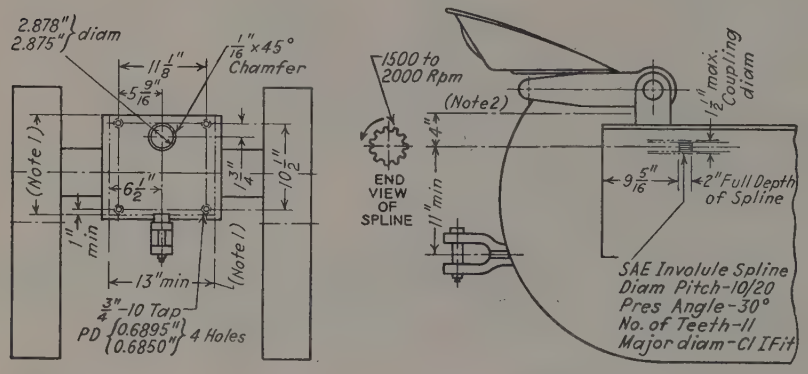


FIG. 1—CLASS I, GROUP 1
(0–25 DRAWBAR HP)

Note 1—Area inside of these lines to be a plane surface for mounting equipment when drawbar brackets and pilot-hole cover are removed. Area between pads around groups of holes can be relieved, but no permanent tractor parts are to project behind this face within this area.

Note 2—Seat or fuel tank shall not project below this line behind the transmission case.

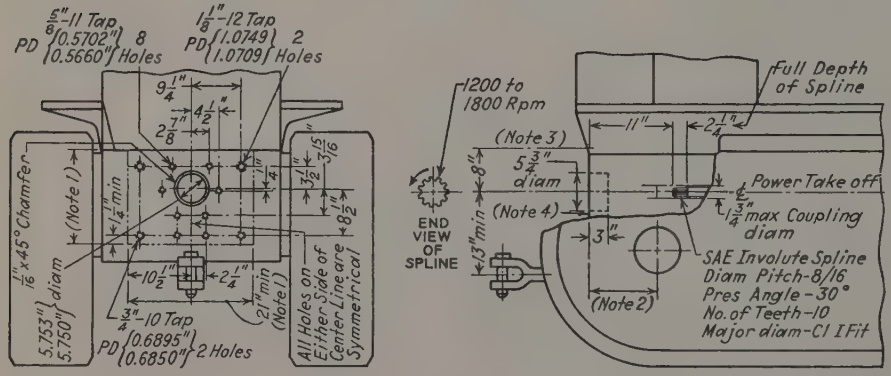


FIG. 2—CLASS I, GROUP 2
(26–35 DRAWBAR HP)

Note 1—Area inside of these lines to be a plane surface for mounting equipment when drawbar brackets and pilot-hole cover are removed. Area between pads around groups of holes can be relieved, but no permanent tractor parts are to project behind this face within this area.

Note 2—Rear face of transmission case should be as close to the sprocket-shaft center as is practical.

Note 3—Seat or fuel tank shall not project below this line behind the transmission case.

Note 4—Minimum clearance inside of transmission case for equipment.

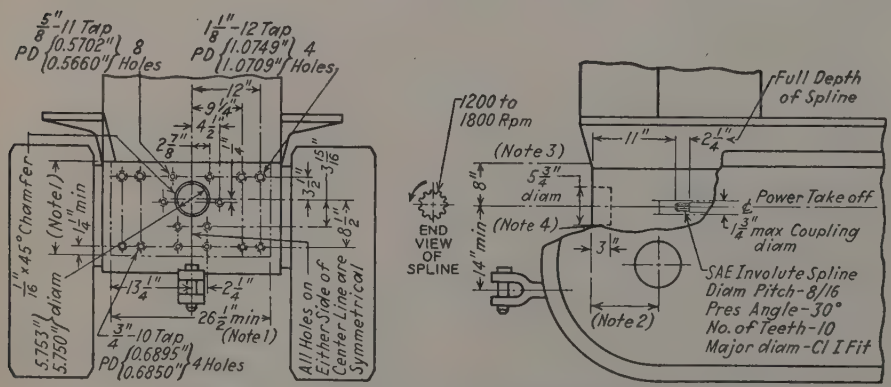


FIG. 3—CLASS I, GROUP 3
(36–50 DRAWBAR HP)

Note 1—Area inside of these lines to be a plane surface for mounting equipment when drawbar brackets and pilot-hole cover are removed. Area between pads around groups of holes can be relieved but no permanent tractor parts are to project behind this face within this area.

Note 2—Rear face of transmission case should be as close to the sprocket-shaft center as is practical.

Note 3—Seat or fuel tank shall not project below this line behind the transmission case.

Note 4—Minimum clearance inside of transmission case for equipment.

(Continued on next page.)

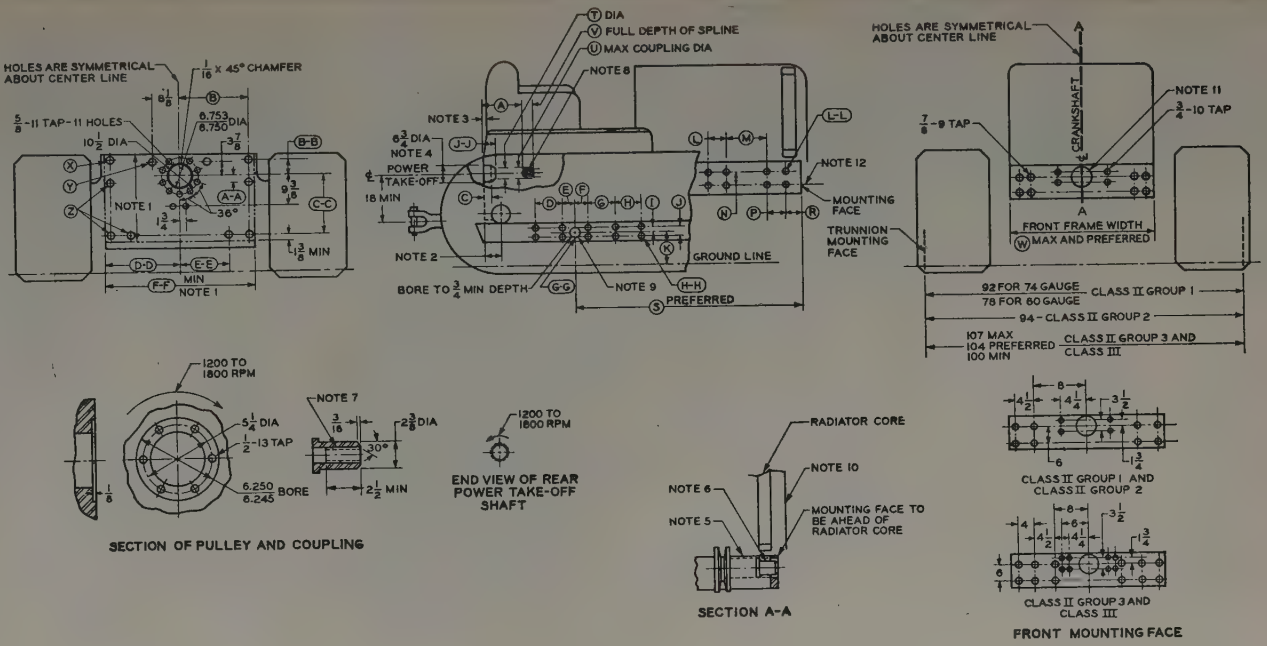


FIG. 4—DIMENSIONS FOR CLASSES II AND III TRACTORS AND FOR EQUIPMENT MOUNTING AND DRIVE FACILITIES

TABLE 1—*Dimensions in Inches for Rear Power Take-Off, Equipment Mounting, and Drive Facilities for Industrial Tractors*

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*P*	*R*	*S*	*T*	*U*	*V*	*W*	*X*	*Y*	*Z*	*A-A*	*B-B*	*C-C*	*D-D*	*E-E*	*F-F*	*G-G*	*H-H*	*J-J*	*K-K*	*L-L*
Class II, Group 1, 51–75 drawbar hp	15	18 5/8	3 1/2	8	4	4	8	8	2	4	12^{+3}_{-0}	5 1/2	16	3	5 1/2	5	82	4	2 7/16	2 1/2	34	1 1/4–12 tap	1 1/4–12 tap	1–14 tap	0	3 7/8	14 3/32	20	12 9/16	40	2.505 2.500 bore	7/8–9 tap	4 3/4	15	7/8–9 tap
Class II, Group 2, 76–100 drawbar hp	15	21 1/8	3 1/2	8	4	4	8	8	2	4	$13\frac{1}{2}^{+3\frac{1}{2}}_{-0}$	5 1/2	16	3	5 1/2	5	100	4	2 7/16	2 1/2	40	1 1/4–12 tap	1 1/4–12 tap	1 1/4–12 tap	1 1/8	3 7/8	15 3/8	22 1/2	14 7/16	45	2.505 2.500 bore	7/8–9 tap	4 3/4	15	7/8–9 tap
Class II, Gr oup 3, 101–125 drawbar hp Class III, 126–175 drawbar hp	19	22 3/16	4 1/2	10	5	5	10	10	2 1/2	5	14^{+4}_{-0}	6	22	4 1/2	6	6	115	4 1/2	3	4	44	1 1/2–12 tap	1 1/4–12 tap	1 1/4–12 tap	1 5/8	4 1/4	19	24	17 3/16	48	3.005 3.000 bore	1–14 tap	5 3/4	18	1–14 tap

Note 1—Area inside these lines to be a plane surface for mounting equipment when drawbar brackets and pilot-hole cover are removed. Area between pads around groups of holes can be relieved, but no permanent tractor parts are to project behind this face within this area.

Note 2—Rear face of transmission case should be as close to the sprocket-shaft center as practical.

Note 3—Rear face of transmission case should be flush with or behind any part of the fuel tank, fenders, or seat frame.

Note 4—Minimum clearance inside of transmission case for equipment.

Note 5—Minimum space for front drive parts from drive flange to front mounting face—4 diameter cylinder.

Note 6—Tractor manufacturer to provide suitable driving element from front drive flange to input shaft of front unit provided with spline and OD as shown.

Note 7—SAE internal involute spline; diametral pitch, 8/16; pressure angle, 30°; number of teeth, 13; major diameter, Class 1 fit.

Note 8—SAE involute spline; diametral pitch, 8/16; pressure angle, 30°; number of teeth, see column *K-K* major diameter, Class 1 fit.

Note 9—Pilot hole not necessarily coincident with bulldozer trunnion.

Note 10—Radiator guard will probably require removal or altering for mounting front units.

Note 11—Centerline of input shaft for front equipment not necessarily coincident with crankshaft center.

Note 12—This row of holes to be 1 in. above bottom row of holes in the front mounting face on Class II Group 1, Class II Group 2, and in line with these holes on Class II Group 3 and Class III.

General Note—Thru holes for equivalent bolt size can be used instead of tapped holes where practical. All tapped holes 7/8-in. diameter and smaller shall be NC thread, and all holes 1-in. diameter and larger shall be NF thread.

Tractor Air-Cleaner Test Code

SAE Recommended Practice

Report of Tractor and Equipment Division approved January 1941.

[*The procedure given in this Recommended Practice is a laboratory method only. When an air cleaner has been developed to a satisfactory point in the laboratory, the final verification of the application must result only from field determinations, as special tests have been found necessary as a result of the particular service to which individual products are subjected.*]

Scope—This test procedure is intended for laboratory use in determining the operating characteristics of air cleaners applied to internal-combustion engines. Either of two procedures may be followed.

(a) *Absolute-Cleaner Method*—The test setup for this procedure interposes an absolute cleaner between the air cleaner on test and the engine. This absolute cleaner catches any dust passed by the air cleaner and provides a direct check on all determinations.

(b) *Direct-Mounting Method*—The test setup for this procedure involves attaching the air cleaner on test to the engine by its regular operating connections.

Because of the check on the results provided by the absolute-cleaner method, this procedure is generally to be preferred. However, should the use of an absolute cleaner be found to affect measurably the performance of the air cleaner, the second method necessarily must be followed.

The entire procedure includes the following determinations:

1. Determination of oil carry-over characteristics and maximum oil level.
2. Determination of minimum oil level.
3. Cleaner efficiency at selected operating level.
4. Cleaner efficiency at selected low oil level.
5. Oil agitation characteristics.
6. Cleaner resistance and horsepower loss.
7. Backfire test.

Apparatus—*Absolute-Cleaner Method*

1. All parts necessary for applying cleaner to engine.

2. Absolute cleaner with sufficient cloths. Cloths to be cut to size from 10 oz Canton flannel, moleskin, or felt weighing not less than 1½ lb per sq yd. New cloths shall be laundered before using. The fuzzy side of moleskin or flannel shall be toward the air flow. The absolute cleaner must be of a size such that the restriction resulting from the collection of dust on cleaner cloths shall not affect engine operation.

3. The dust-feeding apparatus shall be of a type arranged for feeding dust by air flotation. Air fed into the feeding apparatus shall be passed through a suitable air dryer, since moisture contacting the dust causes caking and coagulation. To prevent the accumulation of surface dust on the inside of the dust chamber, which spalls off and enters the air stream in flakes, the dust chamber should be provided with a vibrator.

4. Scales with sufficient capacity and sensitivity to weigh the duster and cleaner to the nearest 0.10 gm or equivalent.

5. Supply of test dust.

6. Water manometers to measure restriction at inlet and outlet of the air cleaner and at the engine inlet.

7. Oil for cleaner tests (SAE 40 and 10W oil of known viscosity characteristics).

8. Compressed-air supply.

9. Suitable data sheets.

Direct-Mounting Method—Provide all apparatus specified for the absolute-cleaner method except the absolute cleaner and cloths.

Test No. 1—Determination of Oil Carry-Over Characteristics and Maximum Oil Level—This test shall be run with 10W oil in the cleaner, with cleaner applied to engine in the regulra manner, and without absolute cleaner. (If an operating application has not been devised, attach cleaner in the simplest manner, using short connections with as few turns as possible.) Submit sketch of setup with report.

1. Fill cleaner with 10W oil to the manufacturer's indicated operating level. Assemble cleaner and weigh to nearest 0.10 gm.

2. Attach cleaner to engine and run for 30 min at full load with wide open throttle.

Air inlet temperature should approximate summer conditions. Record time of start and stop, engine rpm, load, temperature of inlet air, and restriction through cleaner.

3. Remove cleaner and weigh to nearest 0.10 gm. Examine outlet for oil carry over. Record viscosity of oil at temperature of test and the oil loss by weight.

4. If no oil carry over is observed, increase oil level in cleaner by some chosen arbitrary increment and repeat test.

5. Continue at higher oil level increments, as in Step 4 until oil carry over is observed in connections leading from cleaner. Plot cleaner loss in weight against oil level, and from this plotted curve, the maximum operating oil level may be chosen. (Fig. 1 shows a specimen curve plotted from actual tests.)

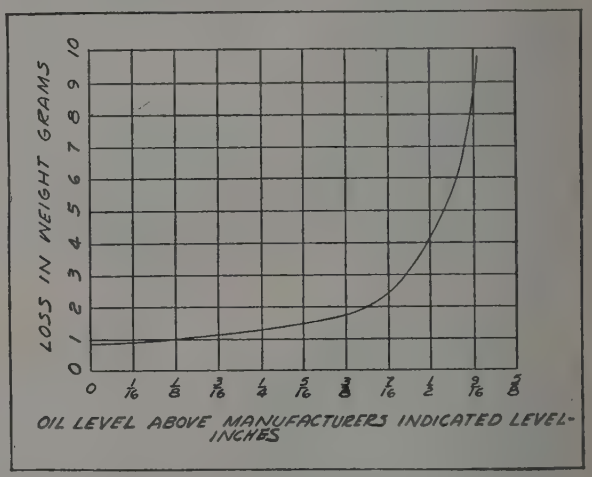

LOSS IN WEIGHT GRAMS
0 1 2 3 4 5 6 7 8 9 10
0 1/16 1/8 3/16 1/4 5/16 3/8 7/16 1/2 9/16 5/8
OIL LEVEL ABOVE MANUFACTURERS INDICATED LEVEL-INCHES

FIG. 1—CLEANER LOSS IN WEIGHT VERSUS OIL LEVEL (SPECIMEN CURVE PLOTTED FROM ACTUAL TESTS)

Note: The maximum oil level must necessarily be selected arbitrarily at some point on the determined curve since, because of oil evaporation, zero oil loss is rarely obtained.

6. As a check, repeat Step 2 for 60 min at chosen maximum oil level.

Test No. 2—Determination of Minimum Oil Level—This test shall be run with SAE 40 oil in the cleaner. Use test setup

as in Fig. 2 with dust-feeding apparatus ahead of cleaner (without absolute cleaner).

1. Run engine at no load and governed speed until operating stability is attained.

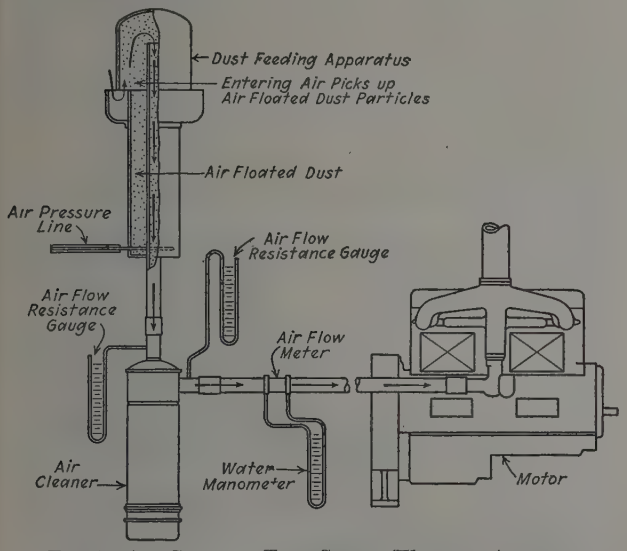


FIG. 2—AIR-CLEANER TEST SETUP (WITHOUT ABSOLUTE CLEANER)

2. Determine lowest oil level at which washing of the separating element is observed. Such observations may be made.

(a) Through window installed in cleaner, or

(b) By removing cup and noting oil draining back from the separating compartment, or

(c) By noting to what degree oil in the cup has been agitated.

3. Run quantitative test at level determined in Step 2 as follows:

(a) Weigh cleaner with oil at above level to nearest 0.10 gm.

(b) Run engine as in Step 1.

(c) Feed dust at 50% of rate used in Test No. 3A, Step 9.

(d) Remove cleaner and weigh to nearest 0.10 gm. Difference between weight in (a) and weight in (d) represents dust retained by cleaner.

4. Repeat Step 3 at a number of oil levels varying by some arbitrarily chosen increment until sufficient data are obtained to permit of choosing the low oil level.

Note: Fig. 3 shows the plotted results of such a series of runs, and from these data the minimum oil level may be selected arbitrarily according to the desired low-level efficiency.

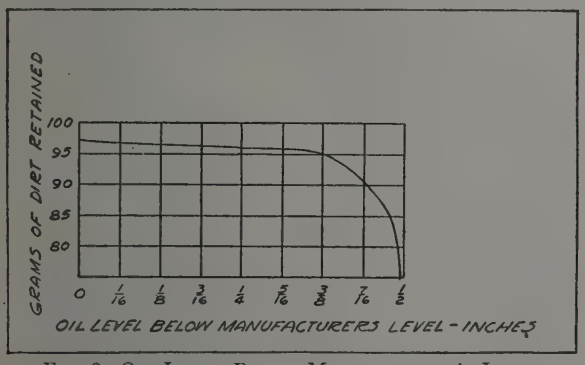


FIG. 3—OIL LEVEL BELOW MANUFACTURER'S LEVEL VERSUS WEIGHT OF DIRT RETAINED

Test No. 3A—Determination of Cleaner Efficiency at Selected Operating Oil Level, Absolute-Cleaner Method—This test shall be run with SAE 40 oil in cleaner.

1. Use test setup shown in Fig. 4 with absolute cleaner between cleaner and engine and dust-feeding apparatus ahead of cleaner.

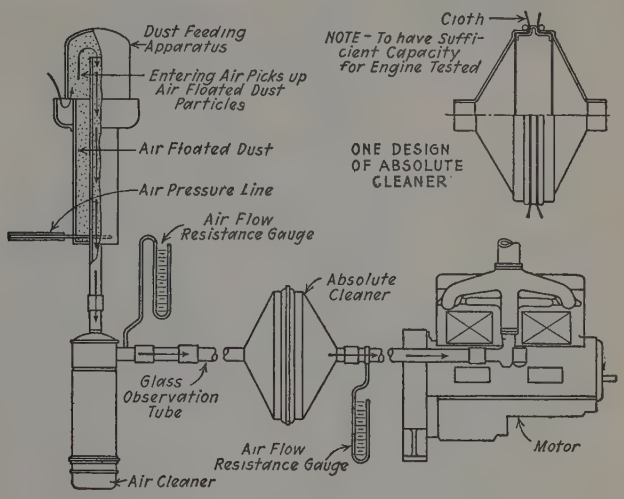


FIG. 4—AIR-CLEANER TEST SETUP WITH ABSOLUTE CLEANER BETWEEN CLEANER AND ENGINE

2. Connection between the various units must be dust and oil tight.

3. A dimensional sketch of the setup shall be submitted with the report.

4. Wash and dry cleaner as in Test No. 5, Steps 1 and 2.

5. Fill cleaner cup with SAE 40 oil to the operating oil level chosen midway between the maximum oil level (Test No. 1) and the minimum oil level (Test No. 2).

6. Wipe inside of absolute cleaner and assemble with thoroughly clean cloths. Install dust feeder, cleaner, and absolute cleaner in series, but do not connect to engine.

7. Fill dust-feeding apparatus with dust, and weigh to nearest 0.10 gm.

8. Start engine and run idle.

9. Connect absolute cleaner to engine and bring engine to full load. At this point, entire setup is complete, but dust is not being floated into the air stream. When ready to start efficiency run, record time and start dust feed at rate of 0.50 gm (or equivalent) per hr for each cfm of air taken into the engine.

10. Maintain dust feed at uniform rate throughout the test and, at 10-min intervals, record intake temperature, engine load, and restriction at both intake and discharge of cleaner. Run test for a period of 4 hr.

11. At end of test, shut off dust feed, record time, and disconnect entire test equipment before stopping engine. Disconnect dust-feed apparatus, and weigh to nearest 0.10 gm. Carefully brush into the cleaner all dust in connections between dust-feed apparatus and cleaner. Disconnect cleaner from absolute cleaner, and brush in absolute cleaner all dust in connections between cleaner and absolute cleaner.

12. Separately wash cleaner, separating element, cleaner cup with oil, and the absolute cleaner with cloths in naphtha, repeating until no discoloration is observed. Filter all naphtha with dust through filter paper, dry, and determine weight increase

of filter paper representing separately the dust removed from the cleaner, separating element, the cleaner cup, and the absolute cleaner.

Note: The quantity of dust removed from the cleaner separating element with respect to that removed from the cup quantitatively indicates the effectiveness of the oil washing throughout the separating element.

Check the accuracy of all determinations by the following:

Weight of dust fed = loss in weight of dust-feeding apparatus
= weight of dust recovered in cleaner + weight of dust recovered in absolute cleaner.

The efficiency may then be calculated as follows:

$$\text{Efficiency } (\%) = 100 \left(\frac{\text{Weight of dust recovered in cleaner}}{\text{Weight of dust recovered in cleaner} + \text{Weight of dust recovered in absolute cleaner}} \right)$$

Test No. 3B—Determination of Cleaner Efficiency at Selected Operating Oil Level, Direct-Mounted Method—This test to be run with SAE 40 oil in cleaner.

1. Use test setup shown in Fig. 2, with dust-feeding apparatus ahead of cleaner.
2. Same as Test No. 3A, Step 2.
3. Same as Test No. 3A, Step 3.
4. Same as Test No. 3A, Step 4.
5. Same as Test No. 3A, Step 5.
6. Same as Test No. 3A, Step 7.
7. Same as Test No. 3A, Step 8.
8. Connect cleaner to engine, and bring engine to full load. At this point, entire setup is complete, but dust is not being floated into the air stream. When ready to start efficiency run, record time and start dust feed at rate established in Test No. 3A, Step 9.
9. Same as Test No. 3A, Step 10.
10. At end of test, shut off dust feed, record time, and disconnect entire test equipment before stopping engine. Disconnect dust-feed apparatus and weigh to nearest 0.10 gm. Carefully brush dust in connections between dust feeder and air cleaner into cleaner.
11. Wash cleaner with oil in naphtha until no discoloration is observed. Filter naphtha with dust through filter paper, dry, and determine weight of dust on filter paper. The cleaner efficiency is then calculated as follows:

$$\text{Efficiency } (\%) = 100 \left(\frac{\text{Weight of dust recovered from cleaner}}{\text{Weight of dust fed}} \right)$$

It will be noted that this method affords no check on dust fed against total dust recovered and should be used only where the use of the absolute cleaner is found to affect the cleaner operation.

Test No. 4—Determination of Cleaner Efficiency at Low Oil Level—This test shall be run with SAE 40 oil in cleaner.

1. Set up and proceed as in Test No. 3A (Steps 1–12) or Test No. 3B (Steps 1–11), except oil level in cleaner shall be at the low level chosen in Test No. 2.
2. Run engine at governed speed without load.

Test No. 5—Oil Agitation Characteristics—Oil agitation may be checked quantitatively under loads varying from no load to full load and at the corresponding governed speeds as follows:

1. Remove entire cleaner from engine, and wash out all oil with naphtha.
2. Dry cleaner as follows:

(a) Blow out the oil separating element with compressed air.

(b) Assemble cleaner. Attach to engine and operate until cleaner is dried thoroughly. This may be determined by weighing cleaner at 5-min intervals until the weight remains constant.

3. Run engine at governed speed and without load, then, without stopping the engine, remove the oil cup and fill to chosen operating oil level (Test No. 3A, Step 5). Weigh cup with included oil to nearest 0.10 gm, and assemble to cleaner.
4. Operate engine at governed speed and without load for a 10-min period.
5. Without stopping engine, remove oil cup with oil and weigh. The reduction in weight from Step 3 represents the oil in the separating compartment.

Note: This test reveals the amount of oil in the separating element which causes the washing action and may be run at any desired load increment to establish the oil agitation characteristics over the load range of the engine.

Test No. 6—Determination of Cleaner Resistance and Horsepower Loss (Carburetor Engine)—Set up cleaner as in Test No. 1 (Fig. 2) without dust-feeding apparatus.

1. Fill cleaner cup with SAE 40 oil to chosen operating oil level (Test No. 3A, Step 5).
2. With throttle maintained in wide-open position and at constant speed, make a maximum fuel characteristic run recording horsepower, fuel consumption, and carburetor adjustment for each point determined. Plot results in curve form. (Specimen is shown in Fig. 5.)

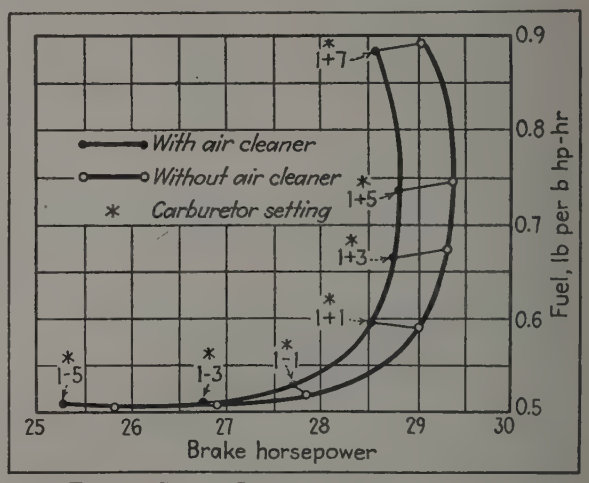


FIG. 5—TYPICAL CURVES PLOTTING RESULTS OF MAXIMUM FUEL CHARACTERISTIC RUN

3. Record engine rpm, temperature, and depression at carburetor inlet.
4. Remove air cleaner from line, leaving intact the remainder of air line from air inlet to inlet. Repeat Step 2 above and plot results on same sheet.
5. Record engine rpm, temperature, and depression at carburetor inlet.
6. The difference between the plotted test results and depression determination gives the horsepower loss and cleaner resistance.

Note: If the carburetor has a fixed adjustment, determine and record the maximum engine horsepower at rated speed.

Preparation of Air-Cleaner Test Dust

SAE General Information

Report of Tractor and Equipment Division approved January 1941.

[*For more complete discussion of this subject, refer to Proposed Air Cleaner Test Code, SAE Journal, July 1940, pp. 294 to 299.*]

Because of the absence of definite information and the almost unanimous lack of agreement on the part of those concerned, it has not been possible to set up a standard test dust, although there is probably no single element affecting to so great a degree the efficiency of an air cleaner as the fineness of the dust used for testing. Satisfactory results in the development of air cleaners having a high degree of field efficiency have been obtained by preparing test dust as follows:

Raw Material—The material shall be dust that settles out of the air behind or around tractors or implements operating in the Salt River Valley, Ariz. It is recommended that this dust be caught on a canvas cloth.

Method of Manufacture

1. Dry raw dust in oven.
2. Sift dust through 200-mesh screen (0.0029-in. width openings).
3. Discard dust retained on 200-mesh screen.
4. Sift dust obtained in Step 2 through a 270-mesh screen (0.0021-in. width opening) until no more will go through.

Screen Analysis (By Weight)—Analysis should be 80% through 270-mesh screen, 20% through 200-mesh screen but shall be retained on 270-mesh screen.

Examination of these specifications reveals:

1. The requirement of air floating results in dust in every way comparable with that entering the air cleaner of a tractor when operating in a field, since the position of the air inlet is such that the greater part of the dust entering the tractor inlet is actually air floated.
2. The specifications of sieve size were arrived at by analyzing samples of dust caught in the oil cups of a number of cleaners operating in the extremely dusty conditions in the Southwest.
3. Examination of air-floated dust from the Salt River Valley of Arizona reveals that it contains a high percentage of extremely fine particles, highly abrasive in nature, the size of which is difficult to arrive at by any screening specifications.

To develop the fallacy of depending solely upon a screen analysis, an examination has been made of such dust as would pass through a 270-mesh wire screen. One of these samples was taken from dust originating in Salt River Valley, Ariz., the other originating in the Imperial Valley at Calexico, Calif. An examination of this dust revealed the following properties:

Particle Size (microns)	*Arizona Dust (%)*	*California Dust (%)*
53 to 44	17.30	5.1
43 to 24	54.2	42.3
23 to 6	15.4	35.9
5 to 0	13.1	16.7

The foregoing analysis indicates that the Arizona dust contains a total of 71.5% of particles larger in size than 23 microns and but 28.5% of 23 microns and smaller; whereas the California dust contains but 47.4% of particles of 23 microns and larger and 52.6% of 23 microns and smaller. Further physical differences lie in the fact that the California dust contained practically three times the hydroscopic moisture contained by the Arizona dust, and 3.2% of the fine particles in the California dust were of a colloidal nature, which greatly increase in volume when in contact with oil and tend to foul the oil-separating element of a cleaner to a point where it can no longer function. It therefore seems that any specification of test dust must, in addition to a particle-size specification, place a limit upon the amount of colloidal matter and the hydroscopic water content.

As to the determination of dust-particle size, there are at present two recognized methods:

1. The elutriation process, based upon Stokes Law covering the time of falling in fluid. This is a microscopic verification of the particle sizes, and determinations by this method reveal the practical accuracy of the results so obtained.
2. The Roller particle-size analyzer, which fractionates the dust particles into graded sizes, based upon Stokes Law in connection with the flow of air.

The results of both methods are in terms of equivalent spheres as given by Stokes Law.

Testing cleaners with a dust made up largely of the finer particles would show less efficiency than would be obtained in field service, but the spread in efficiencies would be magnified. To some, the difference between a cleaner efficiency of 98% and 99% represents but 1%, whereas it should be recognized that the cleaner testing but 98% efficient is passing twice the dust to the engine than does the cleaner testing 99% efficient.

Where finer test dust is used, the cleaner showing an efficiency of 98% with field dust might be lowered to 80% efficiency, while the cleaner showing 99% efficiency with field dust might similarly be lowered in efficiency to 90%. A difference in efficiency between 80% and 90% is more impressive than that between 98% and 99%; yet the ratio of dust passed to the engine is identical.

Haulage and Grader Tires and Off-Highway Rim Classification

SAE Recommended Practice

Report of Construction and Industrial Machinery Technical Committee approved January 1949.

[The tables given in this SAE Recommended Practice were prepared by the SAE Construction and Industrial Machinery Technical Committee as a simplification measure and are published in the SAE Handbook to provide a ready reference guide for designers in the selection of tires.

All section, rim diameter, and ply combinations listed are in accordance with the standards of the Tire and Rim Association except those marked with an asterisk.]

TABLE 1—*Tire and Rim Combinations of Haulage-Type Tires*[a]

SECTION DIAMETER	RIM DIAMETER, IN.				
	20	24	25	29	33
8.25	10 12	—	—	—	—
9.00	10 12	—	—	—	—
10.00	12 14	—	—	—	—
11.00	12 14	—	—	—	—
12.00	14	16	—	—	—
13.00	14	18	—	—	—
14.00	12 16	16 20	—	—	—
16.00	16 20	16 20 24*	—	—	—
18.00	—	—	16 20 24	—	24*
21.00	—	—	16 20 24	20 24	—
24.00	—	—	18 24	24	24
27.00	—	—	—	—	24 30
30.00	—	—	—	—	28 34

[a] All figures included in body of table indicate the ply rating of the particular tire size shown.
The tire manufacturer's data book should be consulted for availability of the desired type of tire.
* These do not appear in Tire and Rim Association Standards.

TABLE 2—*Tire and Rim Combinations of Grader-Type Tires*[a]

SECTION DIAMETER	RIM DIAMETER, IN.		
	20	24	
7.00	10	10	Flat bead
7.50	—	10	Flat bead
8.25	10	—	Flat bead
9.00	—	10	Flat bead
		8	5-deg bead
10.00	—	8	5-deg bead
11.00	—	10	5-deg bead
12.00	—	8 10	5-deg bead
13.00	—	8 12	5-deg bead
14.00	14	10 14*	5-deg bead
16.00	12	14	5-deg bead

[a] All figures included in body of table indicate the ply rating of the particular tire size shown.
The tire manufacturer's data book should be consulted for availability of the desired type of tire.
* This does not appear in Tire and Rim Association Standards.

TABLE 3—*Off-Highway Rim Classification for Haulage Tires*[a]

TIRE SECTION DIAMETER, IN.	RIM WIDTH, IN.
16.00	13.0
18.00	15.0
21.00	17.0
24.00	19.5
27.00	22.0
30.00	22.0

[a] The rim manufacturer's data book should be consulted for availability and other information concerning the desired rim.

Marine Propeller-Shaft Ends and Hubs — SAE Standard

Report of Motorboat and Marine Engine Division approved February 1929 and last revised by Marine Propeller Shaft and Coupling Technical Committee January 1950.

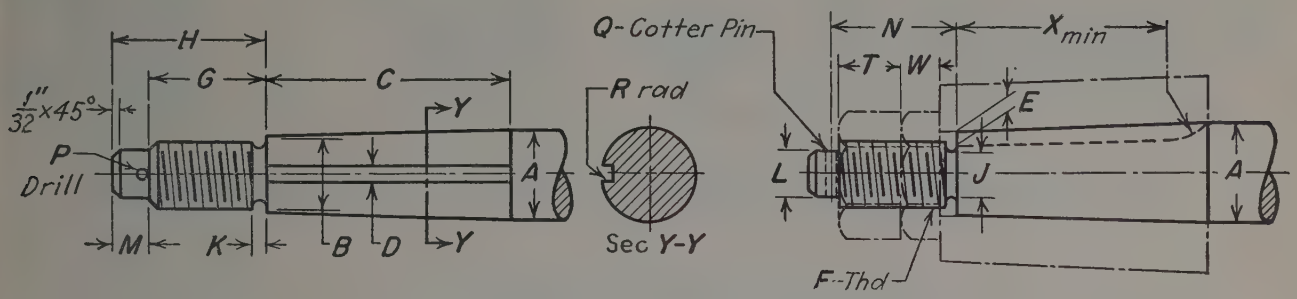


FIG. 1—PROPELLER-SHAFT ENDS
Taper = 3/4 in. on diameter per ft = 1/16 in. per in. = 3° 34′ 47″ total included angle

TABLE 1a—*Dimensions for Shafts from 3/4 to 3 In. in Diameter*

NOM SHAFT DIAM, A	DIAMETER SMALL END, B		TAPER LENGTH, C	KEYWAY WIDTH, D			KEYWAY SIDE DEPTH,[a] E			KEYWAY FILLET RADIUS,[b] R	THREAD,[c] F		END OF TAPER TO END OF THD, G	EXTENSION BEYOND TAPER, H
	Min	Max		Nom	Min	Max	Nom	Min	Max		Diam	Tpi		
3/4	0.624	0.626	2	3/16	0.1865	0.1875	3/32	0.095	0.097	1/32	1/2	13	1 1/16	1 5/16
7/8	0.726	0.728	2 3/8	1/4	0.249	0.250	1/8	0.125	0.127	1/32	5/8	11	1 1/4	1 1/2
1	0.827	0.829	2 3/4	1/4	0.249	0.250	1/8	0.125	0.127	1/32	3/4	10	1 7/16	1 3/4
1 1/8	0.929	0.931	3 1/8	1/4	0.249	0.250	1/8	0.125	0.127	1/32	3/4	10	1 7/16	1 3/4
1 1/4	1.030	1.032	3 1/2	5/16	0.3115	0.3125	5/32	0.157	0.160	1/16	7/8	9	1 5/8	2
1 3/8	1.132	1.134	3 7/8	5/16	0.3115	0.3125	5/32	0.157	0.160	1/16	1	8	1 13/16	2 1/4
1 1/2	1.233	1.235	4 1/4	3/8	0.374	0.375	3/16	0.189	0.192	1/16	1 1/8	7	2	2 7/16
1 3/4	1.437	1.439	5	7/16	0.4365	0.4375	7/32	0.219	0.222	1/16	1 1/4	7	2 1/4	2 3/4
2	1.640	1.642	5 3/4	1/2	0.499	0.500	1/4	0.251	0.254	1/16	1 1/2	6	2 5/8	3 1/8
2 1/4	1.843	1.845	6 1/2	9/16	0.561	0.5625	9/32	0.281	0.284	3/32	1 3/4	5	3	3 1/2
2 1/2	2.046	2.048	7 1/4	5/8	0.6235	0.625	5/16	0.312	0.315	3/32	1 3/4	5	3	3 1/2
2 3/4	2.257	2.259	7 7/8	5/8	0.6235	0.625	5/16	0.313	0.316	3/32	2	4 1/2	3 1/2	4
3	2.460	2.462	8 5/8	3/4	0.7485	0.750	5/16	0.311	0.314	3/32	2 1/4	4 1/2	3 7/8	4 3/8

[a] Keyway shall be cut parallel to taper.
[b] Fillets are recommended for keyways in shafts through 2 in. in diameter. Fillets are mandatory for shafts above 2 in. in diameter.
[c] Threads are Unified and American Standard, Class 3A.

TABLE 1b—*Dimensions for Shafts from 3/4 to 3 In. in Diameter*

NOM SHAFT DIAM, A	UNDERCUT		DIAM OF PIN END, L	LENGTH OF PIN END, M	COTTER-PIN HOLE		COTTER PIN, Q		NUTS[a]			KEYWAY LENGTH, X
	J	K			N	P (drill)	Nom diam	Length	Size	Plain thick, T	Jam thick, W	
3/4	25/64	1/8	3/8	1/4	1 9/64	9/64	1/8	3/4	1/2–13	1/2	5/16	1 1/2
7/8	31/64	1/8	7/16	1/4	1 21/64	9/64	1/8	3/4	5/8–11	5/8	3/8	1 25/32
1	19/32	1/8	1/2	5/16	1 33/64	9/64	1/8	1	3/4–10	3/4	7/16	2 1/8
1 1/8	19/32	1/8	1/2	5/16	1 33/64	9/64	1/8	1	3/4–10	3/4	7/16	2 1/8
1 1/4	23/32	1/8	5/8	3/8	1 23/32	11/64	5/32	1 1/4	7/8–9	7/8	1/2	2 13/16
1 3/8	13/16	1/8	3/4	7/16	1 29/32	11/64	5/32	1 1/2	1 –8	1	9/16	3 5/16
1 1/2	29/32	3/16	7/8	7/16	2 3/32	11/64	5/32	1 1/2	1 1/8–7	1 1/8	5/8	3 1/2
1 3/4	1 1/32	3/16	1	1/2	2 23/64	13/64	3/16	1 3/4	1 1/4–7	1 1/4	3/4	4 7/32
2	1 1/4	3/16	1 1/4	1/2	2 47/64	13/64	3/16	2	1 1/2–6	1 1/2	7/8	4 15/16
2 1/4	1 3/8	3/16	1 3/8	1/2	3 3/64	17/64	1/4	2 1/4	1 3/4–5	1 3/4	1	5 5/8
2 1/2	1 7/16	3/16	1 7/16	1/2	3 3/64	17/64	1/4	2 1/4	1 3/4–5	1 3/4	1	6 3/32
2 3/4	1 11/16	1/4	1 11/16	1/2	3 41/64	17/64	1/4	2 1/2	2 –4 1/2	2	1 1/8	6 21/32
3	1 15/16	1/4	1 15/16	1/2	4 1/64	17/64	1/4	3	2 1/4–4 1/2	2 1/4	1 1/4	7 11/32

[a] Nuts are to be semi-finished stock, American Standard B18.2.

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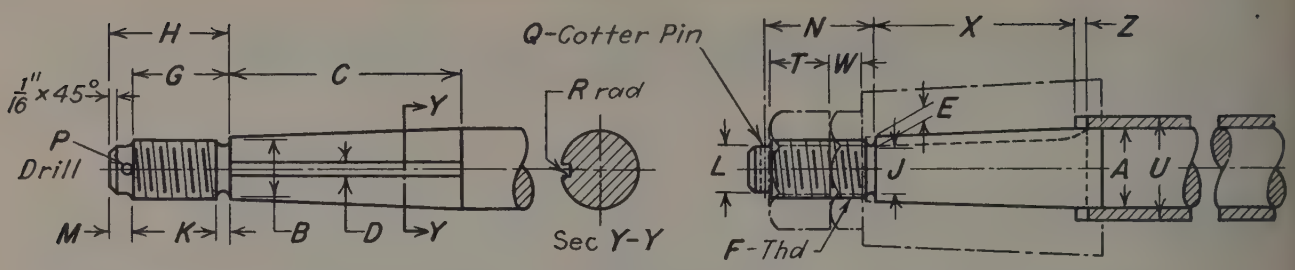

FIG. 2—PROPELLER-SHAFT ENDS

Taper of shafts to 6 in. diameter = ¾ in. on diameter per ft = 1/16 in. per in. = 3° 34′ 47″ total included angle
Taper of shafts 6 in. and larger = 1 in. on diameter per ft = 1/12 in. per in. = 4° 46′ 19″ total included angle

TABLE 2a—*Dimensions of Shafts from 3¼ to 8 In. in Diameter*[a]

NOM SHAFT DIAM, A	DIAMETER SMALL END, B		TAPER LENGTH, C	KEYWAY WIDTH, D			KEYWAY SIDE DEPTH,[b] E			KEYWAY FILLET RADIUS, R	THREAD,[c] F		END OF TAPER TO END OF THD, G	EXTENSION BEYOND TAPER, H	UNDERCUT		DIAM OF PIN END, L
	Min	Max		Nom	Min	Max	Nom	Min	Max		Diam	Tpi			J	K	
3¼	2.663	2.665	9⅜	¾	0.7485	0.750	5/16	0.311	0.314	⅛	2½	4	4⅜	5⅛	2⅛	⅜	2⅛
3½	2.866	2.868	10⅛	⅞	0.8735	0.875	5/16	0.310	0.313	⅛	2½	4	4⅜	5⅛	2⅛	⅜	2⅛
3¾	3.069	3.071	10⅞	⅞	0.8735	0.875	5/16	0.310	0.313	⅛	2¾	4	4¾	5½	2⅜	⅜	2⅜
4	3.272	3.274	11⅝	1	0.9985	1.000	5/16	0.309	0.312	⅛	3	4	5⅛	5⅞	2½	⅜	2½
4½	3.827	3.829	10¾	1⅛	1.123	1.125	⅜	0.373	0.376	5/32	3¼	4	5⅝	6⅜	2¾	⅜	2¾
5	4.249	4.251	12	1¼	1.248	1.250	7/16	0.434	0.437	3/16	3¾	4	6⅜	7⅛	3¼	⅜	3¼
5½	4.671	4.673	13¼	1¼	1.248	1.250	7/16	0.435	0.438	3/16	4	4	6¾	7¾	3½	½	3½
6	4.791	4.793	14½	1⅜	1.373	1.375	½	0.493	0.496	7/32	4¼	4	7½	8½	3⅞	½	3⅞
6½	5.187	5.189	15¾	1⅜	1.373	1.375	½	0.494	0.497	7/32	4½	4	8¼	9¼	4⅜	½	4⅜
7	5.582	5.584	17	1½	1.498	1.500	9/16	0.555	0.558	¼	5	4	9	10	4⅞	½	4⅞
7½	5.978	5.980	18¼	1½	1.498	1.500	9/16	0.556	0.559	¼	5½	4	9⅜	10⅜	5⅛	½	5⅛
8	6.374	6.376	19½	1¾	1.748	1.750	9/16	0.553	0.556	¼	5¾	4	9¾	10¾	5⅜	½	5⅜

[a] A steel shaft may be used in salt water if a suitable aft Fairwater is used.
[b] Keyway shall be cut parallel to taper.
[c] Threads are Unified and American Standard, Class 3A.

TABLE 2b—*Dimensions of Shafts from 3¼ to 8 In. in Diameter*[a]

NOM SHAFT DIAM, A	LENGTH OF PIN END, M	COTTER-PIN HOLE		COTTER PIN, Q		NUTS[b]			SLEEVE DIAM,[c] U		CLEARANCE, Z	KEYWAY, X
		N	P (drill)	Nom diam	Length	Size	Plain thick, T	Jam thick, W	Min	Max		
3¼	¾	4 37/64	⅜	⅜	3	2½–4	2½	1½	3.870	3.872	⅜	8½
3½	¾	4 37/64	⅜	⅜	3	2½–4	2½	1½	4.120	4.122	⅜	9¼
3¾	¾	4 61/64	⅜	⅜	3½	2¾–4	2¾	1⅝	4.369	4.371	⅜	10
4	¾	5 21/64	⅜	⅜	3½	3 –4	3	1¾	4.619	4.621	⅜	10½
4½	¾	—	—	—	—	3¼–4	3¼	1⅞	5.243	5.245	½	9⅝
5	¾	—	—	—	—	3¾–4	3¾	2⅛	5.993	5.995	½	10⅞
5½	1	—	—	—	—	4 –4	4	2¼	6.492	6.494	½	12⅛
6	1	—	—	—	—	4¼–4	4¼	2¼	6.992	6.994	½	13¼
6½	1	—	—	—	—	4½–4	4½	2½	7.492	7.494	½	14⅜
7	1	—	—	—	—	5 –4	5	2¾	8.117	8.120	½	15⅝
7½	1	—	—	—	—	5½–4	5½	3	8.616	8.619	½	16⅞
8	1	—	—	—	—	5¾–4	5¾	3⅛	9.240	9.243	½	18⅛

[a] A steel shaft may be used in salt water if a suitable aft Fairwater is used.
[b] Nuts are to be semi-finished stock, American Standard B18.2.
[c] The shaft sleeve shown is recommended practice, but the use of a sleeve is optional.

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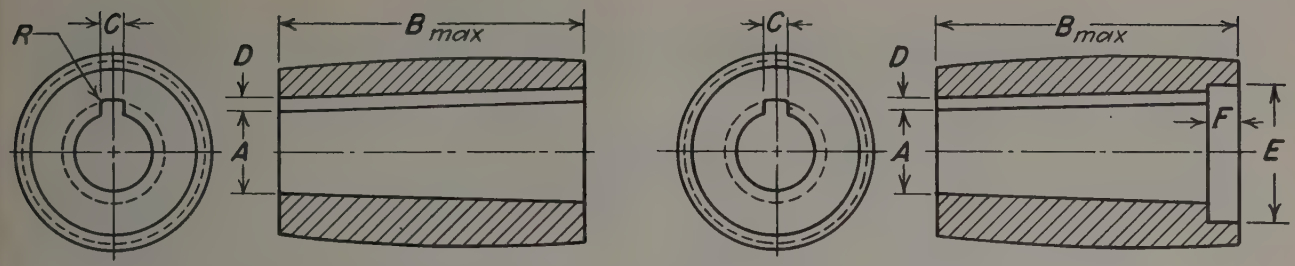

FIG. 3—PROPELLER HUBS

Taper = 3/4 in. on diameter per ft = 1/16 in. per in. = 3° 34′ 47″ total included angle

TABLE 3a—*Hubs for Shafts from 3/4 to 3 In. in Diameter, Inclusive, Without Sleeve*[a]

NOM BORE DIAM	DIAMETER SMALL END, A		LENGTH, B	KEYWAY WIDTH, C			KEYWAY SIDE DEPTH,[b] D			KEYWAY FILLET RADIUS,[c] R
	Min	Max		Nom	Min	Max	Nom	Min	Max	
3/4	0.608	0.610	2 1/4	3/16	0.1865	0.1875	3/32	0.098	0.100	1/32
7/8	0.710	0.712	2 5/8	1/4	0.249	0.250	1/8	0.129	0.131	1/32
1	0.811	0.813	3	1/4	0.249	0.250	1/8	0.129	0.131	1/32
1 1/8	0.913	0.915	3 3/8	1/4	0.249	0.250	1/8	0.129	0.131	1/32
1 1/4	1.015	1.017	3 3/4	5/16	0.3115	0.3125	5/32	0.162	0.165	1/16
1 3/8	1.116	1.118	4 1/8	5/16	0.3115	0.3125	5/32	0.161	0.164	1/16
1 1/2	1.218	1.220	4 1/2	3/8	0.374	0.375	3/16	0.195	0.198	1/16
1 3/4	1.421	1.423	5 1/4	7/16	0.4365	0.4375	7/32	0.226	0.229	1/16
2	1.624	1.626	6	1/2	0.499	0.500	1/4	0.259	0.262	1/16
2 1/4	1.827	1.829	6 3/4	9/16	0.561	0.5625	9/32	0.291	0.294	3/32
2 1/2	2.030	2.032	7 1/2	5/8	0.6235	0.625	5/16	0.322	0.325	3/32
2 3/4	2.233	2.235	8 1/4	5/8	0.6235	0.625	5/16	0.322	0.325	3/32
3	2.437	2.439	9	3/4	0.7485	0.750	5/16	0.323	0.326	3/32

[a] For intermediate sizes and other design data, see Basic Data.
[b] Keyway shall be cut parallel to taper. Keyway side depth is measured normal to axis of taper.
[c] Fillets are recommended for keyways in hubs for shafts through 2 in. in diameter. Fillets are mandatory in hubs for shafts above 2 in. in diameter.

TABLE 3b—*Hubs for Shafts from 3 1/4 to 8 In. in Diameter*[a]

NOM BORE DIAM[b]	SHAFTS WITHOUT SLEEVE										SHAFTS WITH SLEEVE		
	Diameter small end, A		Length, B	Keyway width, C			Keyway side depth, D			Keyway fillet radius, R	Diameter,[c] E		Depth, F
	Min	Max		Nom	Min	Max	Nom	Min	Max		Min	Max	
3 1/4	2.640	2.642	9 3/4	3/4	0.7485	0.750	5/16	0.323	0.326	1/8	3.875	3.878	7/8
3 1/2	2.843	2.845	10 1/2	7/8	0.8735	0.875	5/16	0.324	0.327	1/8	4.125	4.128	7/8
3 3/4	3.046	3.048	11 1/4	7/8	0.8735	0.875	5/16	0.324	0.327	1/8	4.375	4.378	7/8
4	3.249	3.251	12	1	0.9985	1.000	5/16	0.326	0.329	1/8	4.625	4.628	1 1/8
4 1/2	3.796	3.798	11 1/4	1 1/8	1.123	1.125	3/8	0.388	0.391	5/32	5.250	5.253	1 1/8
5	4.218	4.220	12 1/2	1 1/4	1.248	1.250	7/16	0.450	0.453	3/16	6.000	6.003	1 1/8
5 1/2	4.640	4.642	13 3/4	1 1/4	1.248	1.250	7/16	0.450	0.453	3/16	6.500	6.503	1 1/4
6	4.749	4.751	15	1 3/8	1.373	1.375	1/2	0.517	0.520	7/32	7.000	7.003	1 1/4
6 1/2	5.145	5.147	16 1/4	1 3/8	1.373	1.375	1/2	0.516	0.519	7/32	7.500	7.503	1 3/8
7	5.541	5.543	17 1/2	1 1/2	1.498	1.500	9/16	0.579	0.582	1/4	8.125	8.128	1 3/8
7 1/2	5.937	5.939	18 3/4	1 1/2	1.498	1.500	9/16	0.579	0.582	1/4	8.625	8.628	1 3/8
8	6.332	6.334	20	1 3/4	1.748	1.750	9/16	0.582	0.585	1/4	9.250	9.253	1 3/8

[a] For intermediate sizes and other design data, see Basic Data.
[b] On hubs for shafts 6 in. and larger, taper is 1 in. on diameter per ft., equals 1/12 in. per in., equals 4°46′19″ total included angle.
[c] The use of a shaft sleeve is recommended for shafts 3 1/4 in. in diameter and over. The propeller-hub counterbore is to be used only with shafts having the sleeve.

(Continued on next page.)

Tolerances for SAE Marine Tapers—*Surface Finish*—The machined surfaces of propeller hubs and shafting shall be equal to that defined by American Standard B46 as Roughness Symbol 60, which denotes that the root mean square average height of surface irregularities shall not exceed 60 micro inches.

Basic Dimensions—Taper per foot measured on the diameter and diameter of small end of taper shall be basic dimensions.

Taper Tolerances for Hub Bores

Sizes ¾ to 1¼ in. incl., 0.7500 (+0.0000, −0.0020) in. taper per ft

Sizes 1⅜ to 2 in. incl., 0.7500 (+0.0000, −0.0019) in. taper per ft

Sizes 2¼ to 3 in. incl., 0.7500 (+0.0000, −0.0015) in. taper per ft

Sizes 3¼ to 5½ in. incl., 0.7500 (+0.0000, −0.0013) in. taper per ft

Sizes 6 to 8 in. incl., 1.0000 (+0.0000, −0.0013) in. taper per ft

Taper Tolerances for Shafts

Sizes ¾ to 1¼ in. incl., 0.7500 (+0.0020, −0.0000) in. taper per ft

Sizes 1⅜ to 2 in. incl., 0.7500 (+0.0019, −0.0000) in. taper per ft

Sizes 2¼ to 3 in. incl., 0.7500 (+0.0015, −0.0000) in. taper per ft

Sizes 3¼ to 5½ in. incl., 0.7500 (+0.0013, −0.0000) in. taper per ft

Sizes 6 to 8 in. incl., 1.0000 (+0.0013, −0.0000) in. taper per ft

Basic Data—*Keyways*—The keyway shall be cut parallel to taper. At the small end of the hub length and shaft taper length, the keyway shall have the specified side depth. The keyway side depth shall be measured normal to the axis of the taper, not normal to the surface of the taper.

Keys—Keys for use in filleted keyways must be chamfered so that the corners of the key do not touch the keyway fillets.

Small-End Diameter of Taper for Hubs—For nominal bore diameters 3¼ to 4 in. inclusive, the small end of the taper shall be 0.8125 times the nominal bore diameter.

For nominal bore diameters 4½ to 5½ in. inclusive, the small end of the taper shall be 0.84375 times the nominal bore diameter.

For nominal bore diameters 6 to 8 in. inclusive, the small end of the taper shall be 0.79167 times the nominal bore diameter.

Small-End Diameter of Taper for Shafts—For nominal shaft diameters ¾ to 2½ in. inclusive, the small end of the taper shall be 0.8125 times the nominal shaft diameter plus 0.01562 in.

For nominal shaft diameters 2¾ to 4 in. inclusive, the small end of the taper shall be 0.8125 times the nominal shaft diameter plus 0.02344 in.

For nominal shaft diameters 4½ to 5½ in. inclusive, the small end of the taper shall be 0.84375 times the nominal shaft diameter plus 0.03125 in.

For nominal shaft diameters 6 to 8 in. inclusive, the small end of the taper shall be 0.79167 times the nominal shaft diameter plus 0.04167 in.

Intermediate-Size Tapers—The required small-end taper diameter of hub bore and shaft end for intermediate diameters not covered by this Standard shall be calculated from data given above using the next smaller standard taper data.

The keyway for intermediate-size hub bore and shaft end shall be that specified for the next smallest standard bore and shaft.

Marine Propeller-Shaft Couplings — SAE Standard

Report of Motorboat Division approved February 1929 and last revised by Marine Propeller Shaft and Coupling Technical Committee January 1950.

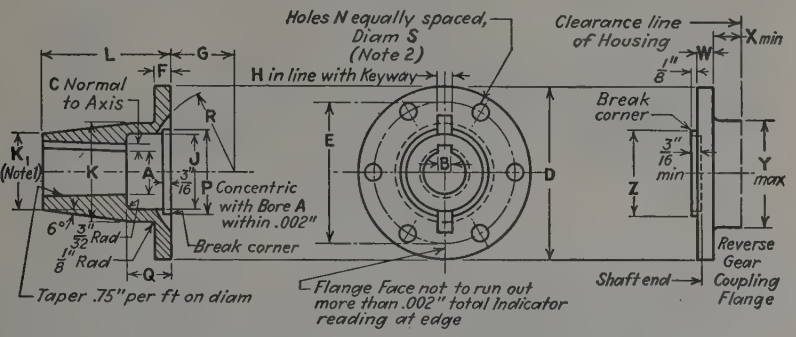

FIG. 1—TYPE I PROPELLER-SHAFT COUPLING, INTERNAL PILOT, TAPER BORE

NOTE 1—Tapered hub is optional

NOTE 2—**No. 1** flange coupling bolt is to be ⅜—24 x 1¼ with plain nut and lockwasher.
No. 2 flange coupling bolt is to be 7/16—20 x 1½ with plain nut and lockwasher.
No. 3 flange coupling bolt is to be ½—20 x 1¾ with plain nut and lockwasher.
No. 4 flange coupling bolt is to be ⅝—18 x 2 with plain nut and lockwasher.

TABLE 1a—*Propeller-Shaft Couplings, Type I, Internal Pilot—Taper Bore*[a]

SAE Flange No.	Shaft Diam Max	D	E	F	G	H	J	K[b]	K_1	L	N
1	1⅛	4	3¼	⅜	17/16	5/16	1¾	2¼	1.856	2⅞	4
2	1½	4¾	3⅞	15/32	1¾	5/16	2¼	2¾	2.252	3⅝	6
3	2	5¾	4¾	9/16	3 3/16	⅜	2¾	3½	2.844	4⅝	6
4	3	7¼	6	⅝	3	⅜	3½	4½	4.500	6½	6

SAE Flange No.	S	P (pilot) Max	P (pilot) Min	Q	R	W	X	Y	Z (pilot) Max	Z (pilot) Min
1	2 5/64	2.002	2.000	1	2	⅜	⅝	2¼	2.000	1.998
2	2 9/64	2.502	2.500	1¼	2½	15/32	11/16	2¾	2.500	2.498
3	3 3/64	3.002	3.000	1½	4	9/16	¾	3½	3.000	2.998
4	4 1/64	3.752	3.750	2	4	⅝	15/16	4½	3.750	3.748

[a] For intermediate sizes, see SAE Standard on Marine Propeller-Shaft Ends and Hubs, Basic Data.
[b] Tapered hub is optional.

TABLE 1b—*Taper-Bore Dimensions*[a]

SAE Flange Number	Shaft Diam Nominal	Bore at A Min	Bore at A Max	B Min	B Max	C[b] Min	C[b] Max
1	¾	0.608	0.610	0.1865	0.1875	0.098	0.100
	⅞	0.710	0.712	0.2490	0.2500	0.129	0.131
	1	0.811	0.813	0.2490	0.2500	0.129	0.131
	1⅛	0.913	0.915	0.2490	0.2500	0.129	0.131
2	1¼	1.015	1.017	0.3115	0.3125	0.162	0.165
	1⅜	1.116	1.118	0.3115	0.3125	0.161	0.164
	1½	1.218	1.220	0.3740	0.3750	0.195	0.198
3	1¾	1.421	1.423	0.4365	0.4375	0.226	0.229
	2	1.624	1.626	0.4990	0.5000	0.259	0.262
4	2¼	1.827	1.829	0.5610	0.5625	0.291	0.294
	2½	2.030	2.032	0.6235	0.6250	0.322	0.325
	2¾	2.233	2.235	0.6235	0.6250	0.322	0.325
	3	2.437	2.439	0.7485	0.7500	0.323	0.326

[a] For intermediate sizes, see SAE Standard on Marine Propeller-Shaft Ends and Hubs, Basic Data.
[b] Keyway shall be cut parallel to taper.

(*Continued on next page.*)

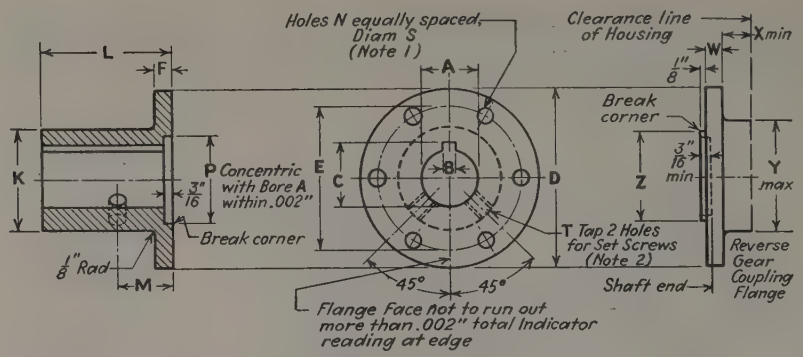

FIG. 2—TYPE I PROPELLER-SHAFT COUPLING, INTERNAL PILOT, STRAIGHT BORE

NOTE 1—No. 1S flange coupling bolt is to be $\frac{3}{8}$—24 x $1\frac{1}{4}$ with plain nut and lockwasher.
No. 2S flange coupling bolt is to be $\frac{7}{16}$—20 x $1\frac{1}{2}$ with plain nut and lockwasher.
No. 3S flange coupling bolt is to be $\frac{1}{2}$—20 x $1\frac{3}{4}$ with plain nut and lockwasher.
No. 4S flange coupling bolt is to be $\frac{5}{8}$—18 x 2 with plain nut and lockwasher.
NOTE 2—Either cone or dogpoint setscrews with spotting of shaft is recommended.

TABLE 2a—*Propeller-Shaft Couplings, Type I, Internal Pilot—Straight Bore*[a]

SAE Flange No.	SHAFT DIAM MAX	D	E	F	K	L	M	N	S
1S	$1\frac{1}{8}$	4	$3\frac{1}{4}$	$\frac{3}{8}$	$2\frac{1}{4}$	$2\frac{7}{8}$	$1\frac{1}{4}$	4	$\frac{25}{64}$
2S	$1\frac{1}{2}$	$4\frac{3}{4}$	$3\frac{7}{8}$	$\frac{15}{32}$	$2\frac{3}{4}$	$3\frac{5}{8}$	$1\frac{5}{8}$	6	$\frac{29}{64}$
3S	2	$5\frac{3}{4}$	$4\frac{3}{4}$	$\frac{9}{16}$	$3\frac{1}{2}$	$4\frac{5}{8}$	$1\frac{7}{8}$	6	$\frac{33}{64}$
4S	3	$7\frac{1}{4}$	6	$\frac{5}{8}$	$4\frac{1}{2}$	$6\frac{1}{2}$	$2\frac{5}{8}$	6	$\frac{41}{64}$

SAE Flange No.	P (PILOT)		T	W	X	Y	Z (PILOT)	
	Max	Min					Max	Min
1S	2.002	2.000	$\frac{3}{8}$–16	$\frac{3}{8}$	$\frac{5}{8}$	$2\frac{1}{4}$	2.000	1.998
2S	2.502	2.500	$\frac{7}{16}$–14	$\frac{15}{32}$	$1\frac{1}{16}$	$2\frac{3}{4}$	2.500	2.498
3S	3.002	3.000	$\frac{1}{2}$–13	$\frac{9}{16}$	$\frac{3}{4}$	$3\frac{1}{2}$	3.000	2.998
4S	3.752	3.750	$\frac{5}{8}$–11	$\frac{5}{8}$	$\frac{15}{16}$	$4\frac{1}{2}$	3.750	3.748

[a] For intermediate sizes, see SAE Standard on Marine Propeller-Shaft Ends and Hubs, Basic Data.

TABLE 2b—*Straight-Bore Dimensions*[a]

SAE Flange Number	SHAFT DIAM NOMINAL	A		B[b]		C	
		Min	Max	Min	Max	Min	Max
1S	$\frac{3}{4}$	0.749	0.750	0.1885	0.1905	0.8378	0.8428
	$\frac{7}{8}$	0.874	0.875	0.2510	0.2530	0.9878	0.9928
	1	0.999	1.000	0.2510	0.2530	1.1151	1.1201
	$1\frac{1}{8}$	1.124	1.125	0.2510	0.2530	1.2419	1.2469
2S	$1\frac{1}{4}$	1.249	1.250	0.3135	0.3155	1.3924	1.3974
	$1\frac{3}{8}$	1.374	1.375	0.3135	0.3155	1.5192	1.5242
	$1\frac{1}{2}$	1.499	1.500	0.3760	0.3780	1.6697	1.6747
3S	$1\frac{3}{4}$	1.749	1.750	0.4385	0.4405	1.9470	1.9520
	2	1.999	2.000	0.5010	0.5030	2.2243	2.2293
4S	$2\frac{1}{4}$	2.249	2.250	0.5635	0.5655	2.5015	2.5065
	$2\frac{1}{2}$	2.499	2.500	0.6260	0.6280	2.7789	2.7839
	$2\frac{3}{4}$	2.749	2.750	0.6260	0.6280	3.0335	3.0385
	3	2.999	3.000	0.7510	0.7530	3.3334	3.3384

[a] For intermediate sizes, see SAE Standard on Marine Propeller-Shaft Ends and Hubs, Basic Data.
[b] Based on Woodruff-key tolerances.

(*Continued on next page.*)

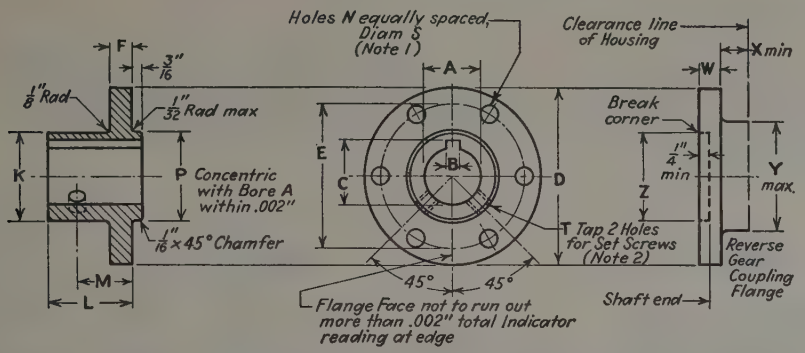

FIG. 3—TYPE II PROPELLER-SHAFT COUPLING, EXTERNAL PILOT, STRAIGHT BORE

NOTE 1—No. 400 flange coupling bolt is to be 3/8—24 x 1 1/2 with plain nut and lockwasher.
No. 500 flange coupling bolt is to be 7/16—20 x 1 5/8 with plain nut and lockwasher.
No. 600 flange coupling bolt is to be 1/2—20 x 1 7/8 with plain nut and lockwasher.
No. 725 flange coupling bolt is to be 5/8—18 x 2 1/4 with plain nut and lockwasher.

NOTE 2—Either cone or dogpoint setscrews with spotting of shaft is recommended.

TABLE 3a—*Propeller-Shaft Couplings, Type II, External Pilot—Straight Bore*

SAE Flange No.	SHAFT DIAM MAX	D	E	F	K	L	M	N	S
400	1 1/4	4	3 1/4	1/2	2	1 7/8	1 1/4	4	25/64
500	1 3/4	5	4 1/8	9/16	2 3/4	2 5/8	1 5/8	4	29/64
600	2 1/4	6	5	5/8	3 1/2	3 3/8	1 7/8	6	33/64
725	3	7 1/4	6	3/4	4 1/2	4 1/2	2 5/8	6	41/64

SAE Flange No.	P (PILOT)		T	W	X	Y	Z (PILOT)	
	Max	Min					Max	Min
400	2.000	1.998	3/8–16	1/2	5/8	2	2.002	2.000
500	2.500	2.498	7/16–14	9/16	11/16	2 3/4	2.502	2.500
600	3.250	3.248	1/2–13	5/8	3/4	3 1/2	3.252	3.250
725	4.250	4.248	5/8–11	3/4	15/16	4 1/2	4.252	4.250

TABLE 3b—*Straight-Bore Dimensions*

SAE Flange No.	SHAFT DIAM NOMINAL	A		B[a]		C	
		Min	Max	Min	Max	Min	Max
400	3/4	0.749	0.750	0.1885	0.1905	0.8378	0.8428
	7/8	0.874	0.875	0.2510	0.2530	0.9878	0.9928
	1	0.999	1.000	0.2510	0.2530	1.1151	1.1201
	1 1/8	1.124	1.125	0.2510	0.2530	1.2419	1.2469
	1 1/4	1.249	1.250	0.3135	0.3155	1.3924	1.3974
500	1 3/8	1.374	1.375	0.3135	0.3155	1.5162	1.5242
	1 1/2	1.499	1.500	0.3760	0.3780	1.6697	1.6747
	1 5/8	1.624	1.625	0.4385	0.4405	1.8197	1.8247
	1 3/4	1.749	1.750	0.4385	0.4405	1.9470	1.9520
600	1 7/8	1.874	1.875	0.5010	0.5030	2.0970	2.1020
	2	1.999	2.000	0.5010	0.5030	2.2243	2.2293
	2 1/4	2.249	2.250	0.5635	0.5655	2.5015	2.5065
725	2 1/2	2.499	2.500	0.6260	0.6280	2.7789	2.7839
	2 3/4	2.749	2.750	0.6260	0.6280	3.0335	3.0385
	3	2.999	3.000	0.7510	0.7530	3.3334	3.3384

[a] Based on Woodruff-key tolerances.

Outboard-Motorboat Transoms

SAE Recommended Practice

Report of Motorboat and Marine Engine Division approved January 1935 and last revised by Marine Propeller Shaft and Coupling Technical Committee October 1950. This SAE Recommended Practice conforms with the standard adopted by a joint committee of the Outboard Boat Manufacturers Association and the Outboard Motor Manufacturers Association in cooperation with the Outboard Boating Club of America.

Lower Unit Clearances—For engines rated up to and including 12 hp, use dotted line (Fig. 1). For engines rated over 12 hp, use solid line.

Transom Width, W—For engines rated up to and including 12 hp, *W* is 6½ in. For engines rated over 12 hp, *W* is 9 in.

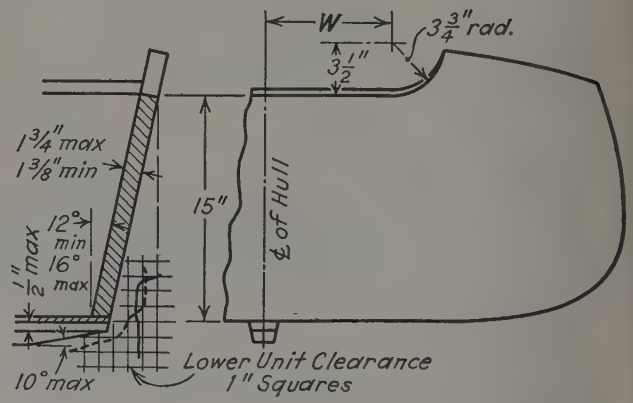

FIG. 1—OUTBOARD-MOTORBOAT TRANSOM DIMENSIONS

Automotive Nomenclature

SAE Standard

Report of Nomenclature Division approved August 1916 and last revised by Passenger Car Division January 1941.

Principles and Rules Governing Automotive Nomenclature

1. Names shall be functional in that they describe the service the part performs, the purpose for which it is used, or its location in an assembled unit.

2. The noun shall appear first in the name, followed by the minimum number of modifiers necessary to definitely define the function of the part. Commonly compounded words shall be broken down into their component parts to assure consistency in the application of this rule.

3. The complete functional name shall incorporate a word designating the group, division, or major assembly to which the part belongs. Exception to this rule shall be made where the basic term without group designation has come to have a recognized application through general usage.

4. Names shall be consistent, and precedent once established in a department or a company should govern the naming of similar and related parts.

5. Unless absolutely necessary for definiteness, compounded names shall not be used even though the part has a dual or multiple function.

6. Where terms *front* and *rear* are used, front should always be toward the front end of the car. Where parts are numbered, No. 1 should be toward the front of the car: For instance, No. 1 cylinder is that nearest the radiator (in a conventional construction). *Right* and *left* are as indicated when sitting in the car facing forward.

Examples of Automotive Nomenclature

Deflector, clutch gear bearing oil
Race, transmission rear bearing
Shim, transmission rear bearing retainer
Boot, universal joint
Retainer, universal joint boot
Armature, generator
Shaft, generator armature
Pinion, differential
Washer, second speed gear thrust
Pin, aileron mounting hinge
Cowling, left motor nacelle

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Primarily to be designed to meet a Military need, it must also be adaptable to any field where mobile lubrication service is desired.

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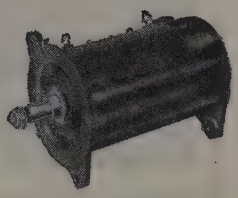
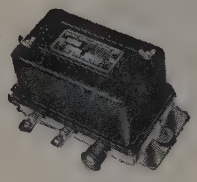


DIRECT CURRENT GENERATORS

60 watts to 2100 watts. Shown above: 14 volt, 50 ampere model. Other types available for any requirements.



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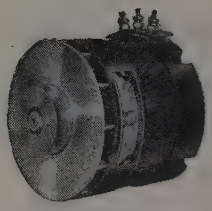
Vibrating and Carbon Pile Types. Hold voltages accurately to close limits.



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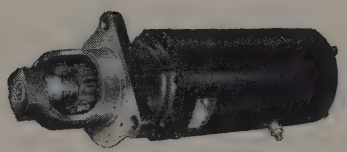

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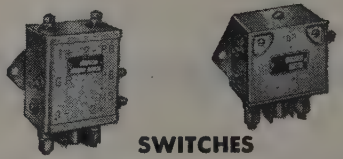

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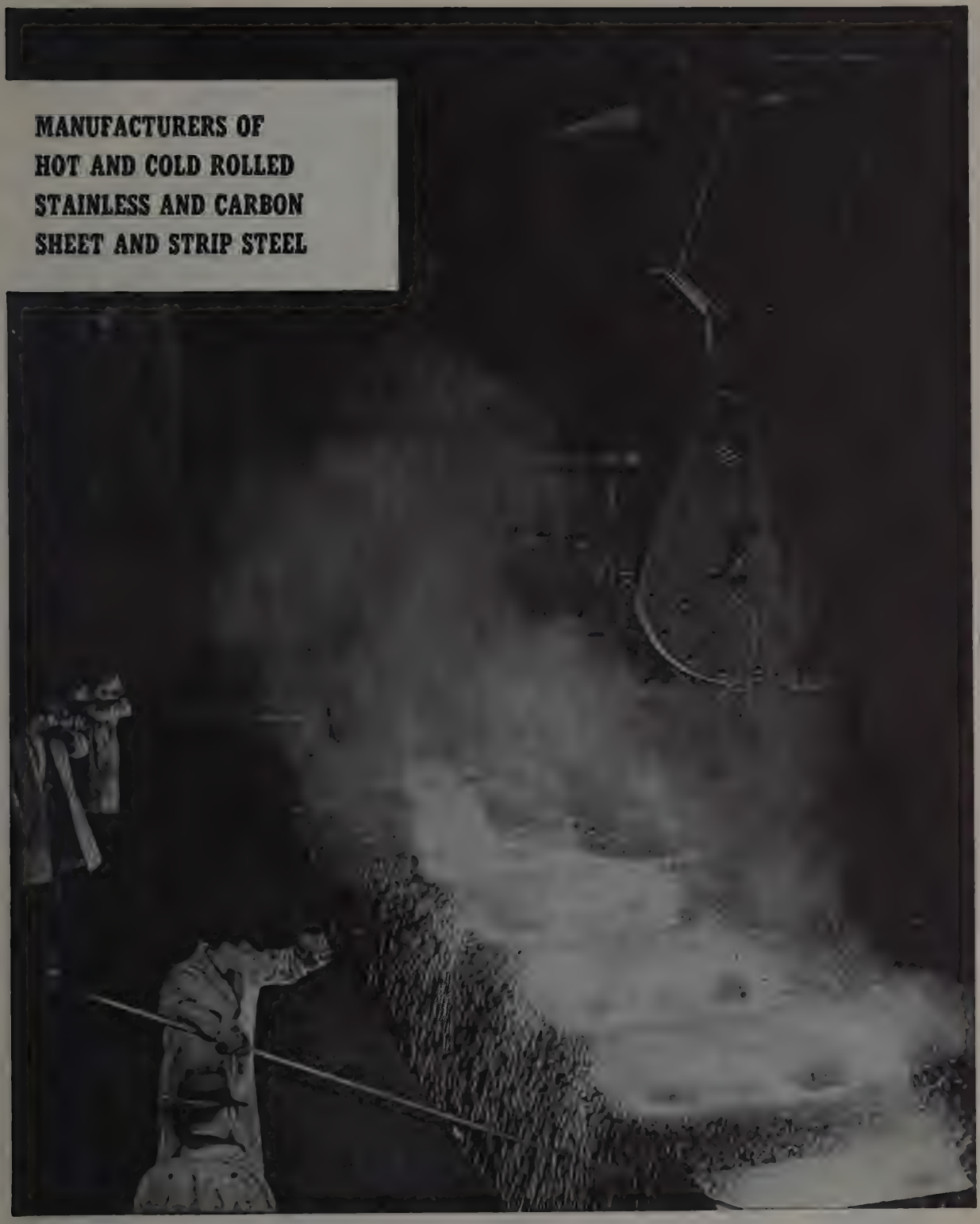

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SAE Designations

MATERIALS AND PARTS	DESIGNATION GIVEN IN SAE STANDARD, SAE RECOMMENDED PRACTICE, OR SAE GENERAL INFORMATION REPORT	PAGE	DESIGNATION (*X* STANDS FOR THE VARIOUS DIGITS)
STEELS—COMPOSITIONS			
Plain Carbon	Chemical Compositions for SAE Carbon Steels[a]	39	SAE 10*XX*
Free-Cutting	Chemical Compositions for SAE Carbon Steels[a]	40	SAE 11*XX*
Manganese Alloy	Chemical Compositions for SAE Alloy Steels[a]	40	SAE 13*XX*
Nickel Alloy	Chemical Compositions for SAE Alloy Steels[a]	41 41	SAE 23*XX* SAE 25*XX*
Nickel-Chromium-Alloy	Chemical Compositions for SAE Alloy Steels[a] Chemical Compositions for SAE Wrought Stainless Steels[a]	41 41 70	SAE 31*XX* SAE 33*XX* SAE 303*XX*
Molybdenum Alloy	Chemical Compositions for SAE Alloy Steels[a]	41	SAE 40*XX*
Chromium-Molybdenum Alloy	Chemical Compositions for SAE Alloy Steels[a]	42	SAE 41*XX*
Nickel - Chromium - Molybdenum Alloy	Chemical Compositions for SAE Alloy Steels[a]	42 43 43 43 43	SAE 43*XX* SAE 86*XX* SAE 87*XX* SAE 93*XX* SAE 98*XX*
Nickel-Molybdenum Alloy	Chemical Compositions for SAE Alloy Steels[a]	42 42	SAE 46*XX* SAE 48*XX*
Chromium Alloy	Chemical Compositions for SAE Alloy Steels[a]	42 42 70	SAE 504*X* SAE 51*XX* SAE 5*X*100
Corrosion-Resistant Casting Alloy	Chemical Compositions for SAE Corrosion- and Heat-Resistant Ferrous Castings	149	SAE 60*XXX*
Chromium-Vanadium Alloy	Chemical Compositions for SAE Alloy Steels[a]	43	SAE 6150
Heat-Resistant Casting Alloy	Chemical Compositions for SAE Corrosion- and Heat-Resistant Ferrous Castings	149	SAE 70*XXX*
Nickel - Chromium - Molybdenum Alloy	Chemical Compositions for SAE Alloy Steels[a]	43 43	SAE 86*XX* SAE 87*XX*
Silicon-Manganese Alloy	Chemical Compositions for SAE Alloy Steels[a]	43	SAE 92*XX*

(*Continued*)

[a] See also Tentative Permissible Variations from Specified Chemical Ranges and Limits for Steels, pages 72 and 73; General Characteristics and Heat-Treatments of Steels, pages 78–89; and Estimated Mechanical Properties of Hot-Rolled and Cold-Finished Carbon Steel Bars, pages 91 and 92.

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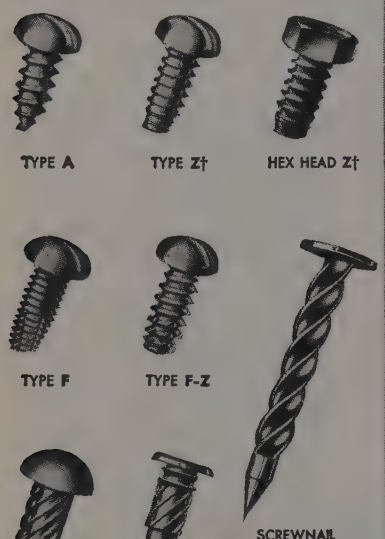
1 The Only Complete Line

Permits you to choose the *right fastener* for the job. No need to fit the *job* to some one type of fastener. The many P-K* *standard* types make it easier to meet your production schedules in these days of limited fastener supplies.



TYPE A | TYPE Z† | HEX HEAD Z†

TYPE F | TYPE F-Z | SCREWNAIL

TYPE U | TYPE 21

†A.S.A. DESIGNATION — TYPE B

2 More Planning Information

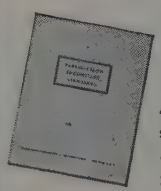
Simplifying your job of digging for data is a continuing project at Parker-Kalon. P-K service literature is highly valued by all assembly planners for its clear, complete, concise information, exactly keyed to their needs.

P-K SCREW SIZE CHART

Wall hanger, 18" x 24", illustrates in actual sizes standard P-K Self-tapping Screws and other fasteners.

P-K CATALOG AND ENGINEERING DATA BOOK

Illustrates and describes the entire P-K line. Tells "where, when, how, and why" P-K Fasteners are used to reduce costs, improve assemblies ... 88 pages.

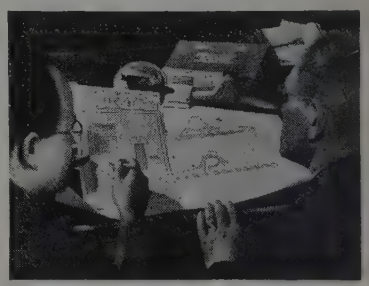


P-K ENGINEERING STANDARDS

A 48-page booklet of standard head and thread dimension drawings of P-K Screws, other data.

3 Experienced Assembly Counsel

As originators and leading producers of hardened Self-tapping Screws, Parker-Kalon has an unequaled 30-year experience covering millions of applications. Based on this experience, a P-K Assembly Engineer's advice can almost invariably help you save time, lower costs, improve product strength.



A P-K Assembly Engineer will call at your request. For service literature, write:
Parker-Kalon Corporation,
200 Varick St., New York 14.

The Original

PARKER-KALON* SELF-TAPPING SCREWS

Other P-K Products — COLD-FORGED SOCKET SCREWS, WING NUTS, THUMB SCREWS
HARDENED SCREWNAILS AND MASONRY NAILS

*TRADE MARKS REG. U.S. PAT. OFF.

SAE DESIGNATIONS

MATERIALS AND PARTS	DESIGNATIONS GIVEN IN SAE STANDARD, SAE RECOMMENDED PRACTICE, OR SAE GENERAL INFORMATION REPORT	PAGE	DESIGNATION (*X* STANDS FOR THE VARIOUS DIGITS)
STEELS—COMPOSITIONS—*Cont.*			
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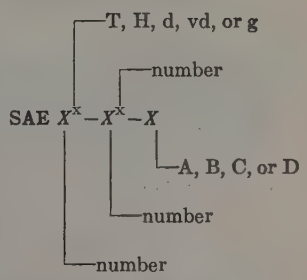
STEELS — HIGH - STRENGTH, LOW-ALLOY	High-Strength, Low-Alloy Steel, SAE 950	74	SAE 950
STEELS—INCLUSION CLASSIFICATIONS	Determination of Inclusions in Steels	131	 (for example, 7^T-2^3-B)
FERROUS CASTINGS			
Gray Iron	Automotive Gray Iron Castings	140	SAE 11*X*
		140	SAE 12*X*
Malleable Iron	Automotive Malleable Iron Castings	142	Grade 32510
		142	Grade 35018
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Plain-Carbon and Low-Alloy Steel	Automotive Steel Castings	145	SAE Grade 0022
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		145	SAE Grade 0050
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High-Strength Steel Compositions	Automotive Steel Castings	146	SAE Grade 0105
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		146	SAE Grade 0175

(*Continued*)

SHARONSTEEL

Pig Iron . . . Open Hearth and Electric Furnace grades of Steel . . . Ingots, Blooms, Slabs, Billets, Sheet Bar, Tube Rounds . . . U. M. Plates . . . Hot Rolled Strip and Sheets—Black, Pickled—Coils and Cut Lengths . . . Low Carbon, High Carbon and Razor Blade Analyses . . . Cooperage Hoop . . . Cold Rolled Strip . . . Cold Rolled Spring Steel . . . Terne Coated Strip . . . Galvanite . . . Stainless Steel Strip—Hot Rolled and Cold Rolled . . . Alloy Steel—Open Hearth and Electric Furnace grades . . . High Tensile Low Alloy Strip . . . Anti-Checking Irons.

SHARON STEEL CORPORATION

Sharon, Pennsylvania

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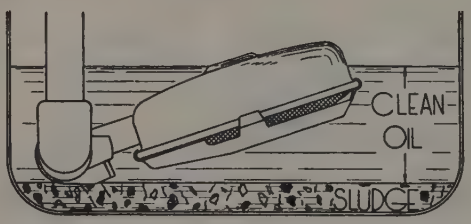
FLOAT-O

Supplies bearings with the "Cream" of the Oil . . . from the top of the Crankcase



The sludge, filings and heavy abrasives which cause serious engine wear and inefficiency naturally precipitate to the bottom of the crankcase. FLOAT-O, installed at the pump intake, draws horizontally from the clean oil found at the top . . . it does not disturb the harmful substances found at the bottom of the crankcase. With FLOAT-O only this "cream" of the oil sump is distributed to the bearings. This is true during starting and all running conditions. FLOAT-O is also a definite guarantee against ice-locking. Indorsed and approved by the leading research engineers of the industry, FLOAT-O insures quicker starting, smoother operation and longer life for engines.

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Plymouth
Reo Motors
Seagrave Corp.
Sterling Engine
Studebaker
Waukesha Motors
White Motors
Willys-Overland
Wolseley Motors, Ltd.

SAE DESIGNATIONS

MATERIALS AND PARTS	DESIGNATION GIVEN IN SAE STANDARD, SAE RECOMMENDED PRACTICE, OR SAE GENERAL INFORMATION REPORT	PAGE	DESIGNATION (*X* STANDS FOR THE VARIOUS DIGITS)
FERROUS CASTINGS—*Cont.*			
High-Strength Steel specified by hardenability	Automotive Steel Castings	147	SAE 01*XX* H—*XX* 1, 2, 3, 4, or 5 A, B, C, or D composition (for example, SAE 0105 H-2C)
Corrosion-Resistant Steel	Chemical Compositions of SAE Corrosion- and Heat-Resistant Ferrous Castings	149	SAE 60*XXX*
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(*Continued*)

"no more GAMBLING on tool steel selection"

[⅓ actual size; Selector is in 3 colors]

Since the first announcement, hundreds of tool steel users have received their CRUCIBLE TOOL STEEL SELECTORS. The comments received indicate that this handy method of *picking the right tool steel right from the start* is going over big.

"Handiest selector I've ever seen"

"No more gambling on tool steel selection"

"You're right, the application should dictate the choice of the tool steel"... and many, many more favorable comments.

You'll want your CRUCIBLE TOOL STEEL SELECTOR. It uses the only logical method of tool steel-selection—begin with the application to pick the right steel! And the answer you get with one turn of the Selector dial will prove satisfactory in every case, for the CRUCIBLE TOOL STEEL SELECTOR covers 22 tool steels which fit 98% of all Tool Steel applications. ALL the tool steels on the Selector are in Warehouse Stock...that means when you get the answer, you can get the steel...fast!

Write for your Selector today! We want you to have it, because we know you've never seen anything that approaches your tool steel problems so simply and logically. Just fill out the coupon and mail. Act now! CRUCIBLE STEEL COMPANY OF AMERICA, Chrysler Building, New York 17, N. Y.

Here's how it works:

To use the Selector, all you need know is the characteristics that come with the job: type and condition of material to be worked, the number of pieces to be produced, the method of working, and the condition of the equipment to be used.

FOUR STEPS—and you've got the right answer!

1. Move arrow to major class covering application
2. Select sub-group which best fits application
3. Note major tool characteristics (under arrow) and other characteristics in cut-outs for each grade in sub-group
4. Select tool steel indicated

That's all there is to it!

Here's an example:

Application—Deep drawing die for steel

Major Class—Metal Forming—Cold

Sub-Group—Special Purpose

Tool Characteristics—Wear Resistance

Tool Steel—Airdi 150

One turn of the dial does it!

And you're sure you're right!!

Crucible Steel Company of America
Dept. SAE, Chrysler Building, 405 Lexington Avenue
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SAE DESIGNATIONS

MATERIALS AND PARTS	DESIGNATION GIVEN IN SAE STANDARD, SAE RECOMMENDED PRACTICE, OR SAE GENERAL INFORMATION REPORT	PAGE		DESIGNATION (*X* STANDS FOR THE VARIOUS DIGITS)	
COPPER ALLOYS					
Casting Alloys	Copper-Base Casting Alloys	173	173	SAE 40	SAE 63
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		173	173	SAE 430B	SAE 66
		173	173	SAE 62	SAE 660
		173	173	SAE 620	SAE 67
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		174, 175	174	SAE 71	SAE 791
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			209	SAE 510	
			209, 210	SAE 52	
			209, 210	SAE 52*X*	
			209, 210	SAE 53	
			209, 210	SAE 53*X*	

(*Continued*)

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with PRECISION *Die Castings*

Light, strong, durable Precision Die Castings can lower your production costs and enable you to turn out a finer finished, more saleable product. Die cast to hold closer tolerances, Precision Die Castings often eliminate many expensive assembly operations, when designed to your special needs.

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LONG MILEAGE • ENGINE CLEANLINESS • LONG ENGINE LIFE

By the makers of BLUE SUNOCO gasoline

SUN OIL COMPANY

Philadelphia, Pa.

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ZINC ALLOYS	Zinc Die-Casting Alloys	212, 213 212, 213 212, 213	SAE 903 SAE 921 SAE 925
BEARING ALLOYS			
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Cadmium Alloys	Main and Connecting-Rod Bearing Alloys	220 220	SAE 18 SAE 180
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Copper Alloys	Main and Connecting-Rod Bearing Alloys	221 221 221 221 221 221 221 221	SAE 791 SAE 795 SAE 792 SAE 797 SAE 793 SAE 798 SAE 794 SAE 799
SOLDERS	Solders	225 225 225 225 225 225 225 225 225 225 225 225	SAE 1A SAE 4A SAE 1B SAE 4B SAE 2A SAE 5A SAE 2B SAE 5B SAE 3A SAE 6A SAE 3B SAE 6B
ELECTROPLATING THICKNESSES	Electroplating Practice	227 227 227 227 227 227 227 227 227 227	DS FS FZ FC KS KZ KC QS QZ QC
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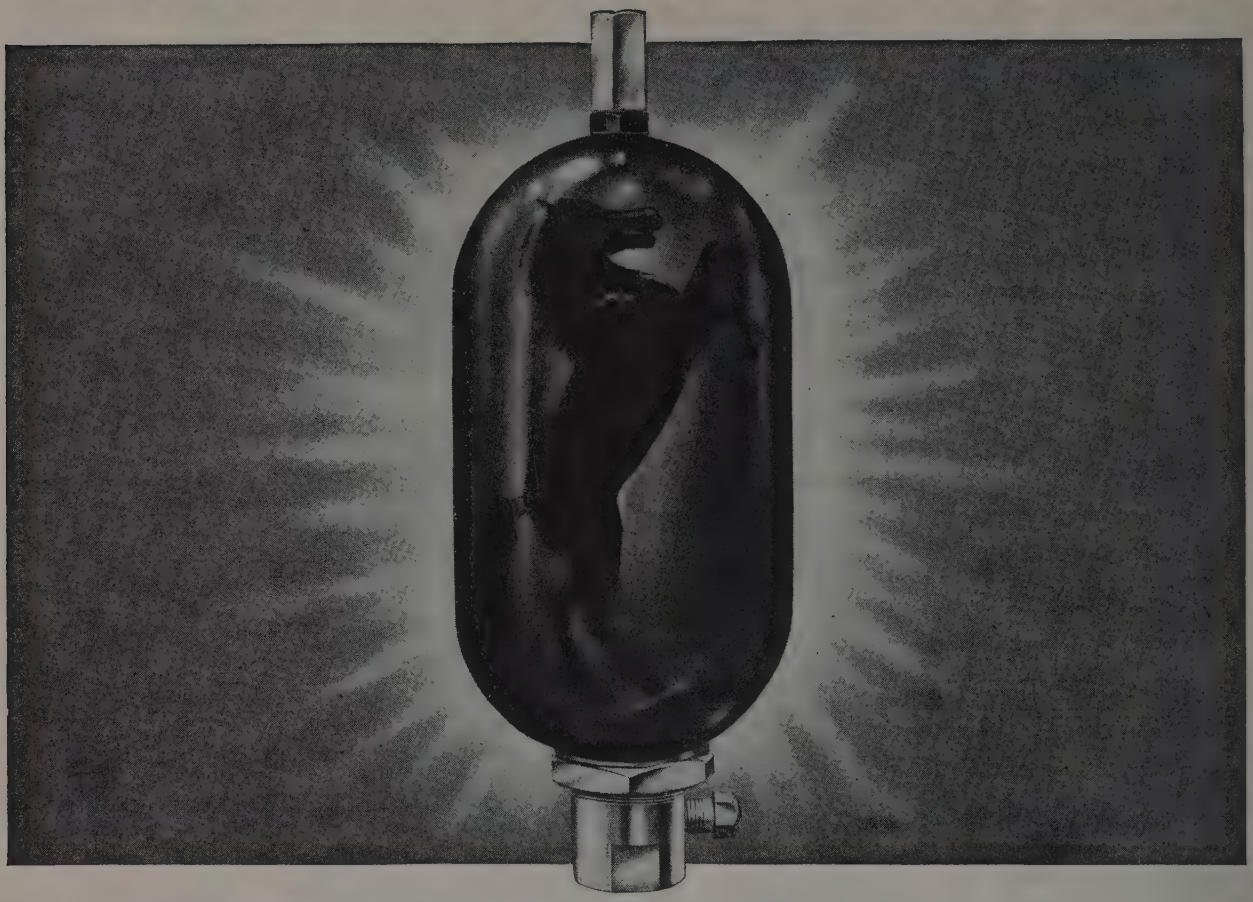
Fuel and Oil Hoses	Fuel and Oil Hoses (**SAE R 30**)	239–243	SAE R 31–SAE R 34

(*Continued*)

CANNED HORSEPOWER!



Stored horsepower in Greer Accumulators boosts efficiency of hydraulic systems!

ACTUAL CASE HISTORY FROM OUR FILES

"Incorporating a Greer Accumulator in our 31,000 pound manipulator saved 9 hours machining time, 1 hour of assembly time, 20% floor space and reduced the actual cost of manufacture", writes S. T. Morgan, chief engineer, Edgar E. Brosius Co. Inc. Pittsburgh.

Will they do even more than this for you? Get the facts from our engineers! Call or write for Greer Bulletin 300.

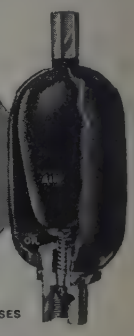
Take a 50-ton hot metal press and add a pair of Greer Accumulators to the system. The result is incredible! The 50-horsepower motor that formerly ran the press is replaced by a 1½-horsepower motor which does nothing but pump oil to the accumulator. Full power at every stroke—restored between cycles.

Improved performance is the other part of the story. Greer Accumulators are used as "shock-absorbers" in many hydraulic systems—cushioning pulses of powerful pumps, for example.

What else can these mighty midgets do? They can compensate for pressure valve leaks, dispense fluids, provide auxiliary or emergency power sources, pressure transfer barriers and power supply for secondary circuits.

If you have anything to do with *any* hydraulic system, it will pay you to look carefully into Greer Accumulators.

GREER ACCUMULATORS



U. S. PATENTS UNDER OLEAR LICENSES

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MATERIALS AND PARTS	DESIGNATION GIVEN IN SAE STANDARD, SAE RECOMMENDED PRACTICE, OR SAE GENERAL INFORMATION REPORT	PAGE	DESIGNATION (*X* STANDS FOR THE VARIOUS DIGITS)
RUBBER HOSES—*Cont.*			
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Medium-Carbon, Cold-Worked Studs Only		137–139	**Grade 4**
Medium-Carbon, Quenched- and-Tempered Bolts		137–139	**Grade 5**
Medium-Carbon, Quenched- and-Tempered, High-Strength Bolts		137–139	**Grade 6**
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(*Continued*)

When Tubing Problems are TOUGH...

You can CUT COSTS • SPEED PRODUCTION • IMPROVE QUALITY with GM Tubing

⅛" to ⅝" O.D.
SINGLE and DOUBLE WALLS OF STEEL

In the automotive field . . . and in the closely related fields of refrigeration, heating and air conditioning . . . GM Steel Tubing has proved its ability to meet or exceed the toughest strength, ductility, cleanliness and pressure requirements—and still provide *faster production* at *lower cost.* In addition, Rochester Products offers complete fabricating facilities, including the services of experienced GM engineers.

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GM Fuse-Kote is the name given to the exclusive protective finish or coating applied to welded GM Steel Tubing. It means greater safety, new ease and speed in forming and sizing, improved corrosion resistance, and oxide-free surface for welding and soldering.

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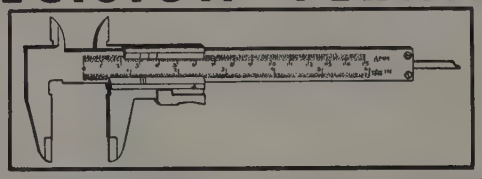
AMIC PRECISION VERNIER TOOLS



6" AMIC QUICK ACTION CALIPERS
#21B, INCH GRADUATION ONLY, 1/1000" Readings
#22B, INCH AND METRIC GRADUATION, 1/1000" and 1/10mm Readings
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AMIC

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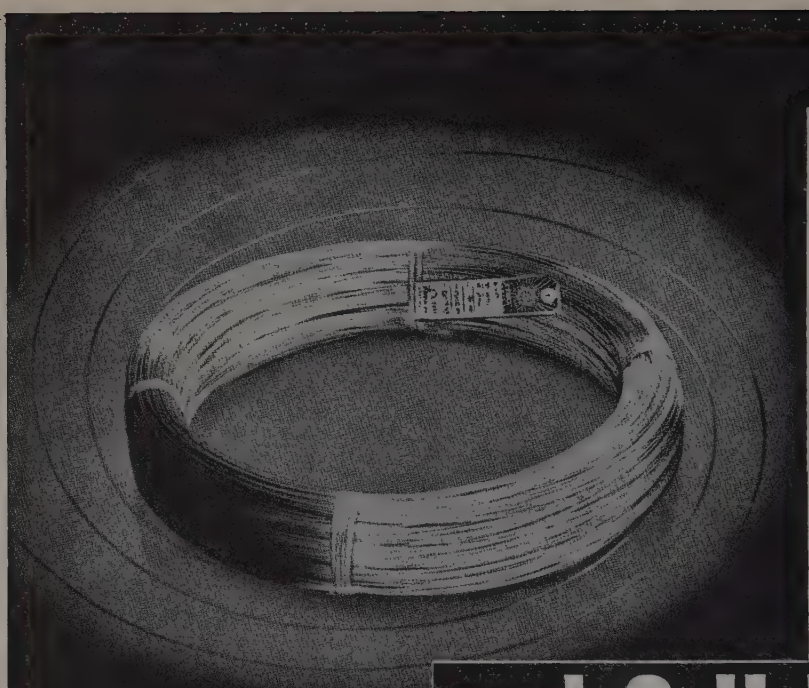
Cable Address: AMICTOOL

SAE DESIGNATIONS

MATERIALS AND PARTS	DESIGNATION GIVEN IN SAE STANDARD, SAE RECOMMENDED PRACTICE, OR SAE GENERAL INFORMATION REPORT	PAGE	DESIGNATION (*X* STANDS FOR THE VARIOUS DIGITS)
BEARINGS, ANTIFRICTION			
Ball Bearings, Type BC	Antifriction Ball and Roller Bearings	579, 581, 582	6BC02, . . ., 150BC03
Ball Bearings, Type BN	Antifriction Ball and Roller Bearings	579, 581, 582	10BN02, . . ., 60BN03
Ball Bearings, Type BL	Antifriction Ball and Roller Bearings	579, 581, 582	20BL02, . . ., 90BL03
Ball Bearings, Type BA	Antifriction Ball and Roller Bearings	579, 581, 582	10BA02, . . ., 100BA02
Ball Bearings, Type BS	Antifriction Ball and Roller Bearings	579, 581–583	12BS02, . . ., 75BS23
Ball Bearings, Type BT	Antifriction Ball and Roller Bearings	579, 581, 583	20BT02, . . ., 90BT02
Ball Bearings, Type BIC	Antifriction Ball and Roller Bearings	583	2BIC00, . . ., 24BIC00
Ball Bearings, Type BM	Antifriction Ball and Roller Bearings	579, 583	2BM02, . . ., 17BM003
Ball Bearings, Type BE	Antifriction Ball and Roller Bearings	579, 584	10BE32, . . ., 110BE32
Ball Bearings, Type BD	Antifriction Ball and Roller Bearings	579, 584	10BD33, . . ., 110BD32
Ball Bearings, Type BAF	Wheel Ball Bearings	579, 586	12BAF401, . . ., 22BAF462
Ball Bearings, Type BCB	Wheel Ball Bearings	579, 586	35BCB082, . . ., 45BCB088
Ball Bearings, Type BWF	Fan and Water-Pump Ball Bearings	579, 587	BWF229, . . ., BWF340
Ball Bearings, Type TK	Clutch-Release Ball Bearings	580, 588	22TK306, . . ., 44TK302
Ball Thrust Bearings, Type TA	Ball Thrust Bearings	580, 599	10TA025, . . ., 140TA026
Ball Thrust Bearings, Type TB	Ball Thrust Bearings	580, 600	8TB030, . . ., 56TB030
Ball Thrust Bearings, Type TN	Clutch-Release Ball Bearings	580, 589	306TN342, . . ., 337TN332
Cylindrical Roller Bearings, Type RN	Cylindrical Roller Bearings	580, 590	17RN02, . . ., 150RN03
Self-Aligning Roller Bearings, Type SD	Cylindrical Roller Bearings	580, 591	35SD02, . . ., 150SD23
Self-Aligning Roller Bearings, Type SW	Cylindrical Roller Bearings	580, 591	40SW23, . . ., 150SW23
Needle Bearings, Type NCD	Needle Roller Bearings	580, 591	6NCD1212, . . ., 30NCD2440
Loose Rollers, Type L	Needle Roller Bearings	580, 591	0312L19, . . ., 0938L88
Taper Roller Bearings	Taper Roller Bearings	593–596	*XXX*-*XXX*
		593–597	*XXXX*-*XXXX*
		593–597	*XXXXX*-*XXXXX*
			A*XXXX*-A*XXXX*
		597	EE*XXXXXX*-*XXXXXX*
		580, 598	NA*XXX*-*XXX*D
		580, 598	NA*XXXXX*-*XXXXX*D
		593	(See Standard)

(*Continued*)



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NEW HAVEN, CONN.

SAE DESIGNATIONS

MATERIALS AND PARTS	DESIGNATION GIVEN IN SAE STANDARD, SAE RECOMMENDED PRACTICE, OR SAE GENERAL INFORMATION REPORT	PAGE	DESIGNATION (*X* STANDS FOR VARIOUS DIGITS)
LOCK NUTS FOR BALL AND CYLINDRICAL ROLLER BEARINGS	Ball- and Roller-Bearing Lock Nuts and Washers	575–577 575–577	N-00–N-14 AN-15, . . ., AN-40
LOCK NUTS FOR TAPER ROLLER BEARINGS	Ball- and Roller-Bearing Lock Nuts and Washers	575–577 575–577	8-N-00-8-N-14 8-AN-15, . . ., 8-AN-140
LOCK WASHERS FOR BALL AND ROLLER BEARINGS	Ball- and Roller-Bearing Lock Nuts and Washers	575–577 575–577	W-00, . . ., W-40 W-102, . . ., W-140
CABLE—INSULATED	Insulated Cable	645 645 645 645 645	SAE 0000 SAE 000 SAE 00 SAE 0 SAE 1, . . ., SAE 20
CABLE TERMINAL—STUD OR SCREW AND HOLE OR SLOT SIZES	Cable Terminals	652	SAE 1–SAE 9
CABLE TERMINALS			
Straight-Type Eyelet Terminals	Cable Terminals	652 652 652 652	SAE A00*X* SAE B10*X* SAE B20*X* SAE B30*X*
Offset-Type Eylet Terminals	Cable Terminals	653	SAE C40*X*
Straight-Type Spade Terminals	Cable Terminals	653 653 653	SAE H00*X* SAE H10*X* SAE H20*X*
Side-Type Spade Terminals	Cable Terminals	654 654	SAE M10*X* SAE M20*X*
Side-Type Eyelet Terminals	Cable Terminals	655 655 655	SAE K10*X* SAE K20*X* SAE K30*X*
End-Type Starting-Cable Terminals	Cable Terminals	656 656 656 656	SAE N40*X* SAE N50*X* SAE N60*X*a SAE N60*X*b
FUSE CAPACITIES	Electric Fuses	661 661 661 661 661 661	4 14 6 20 9 30

(*Continued*)

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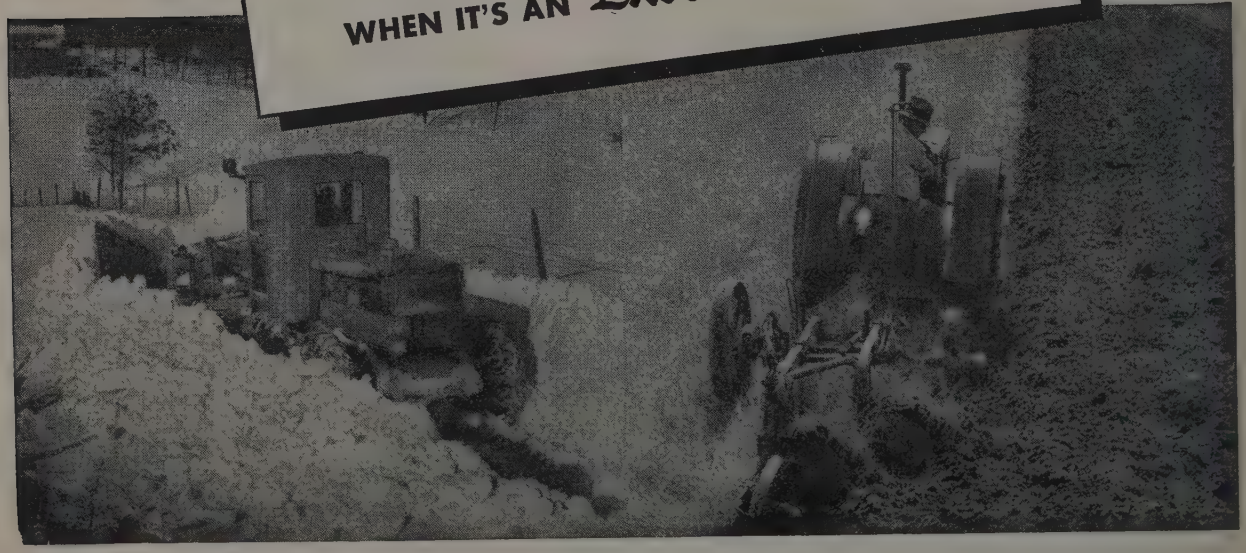
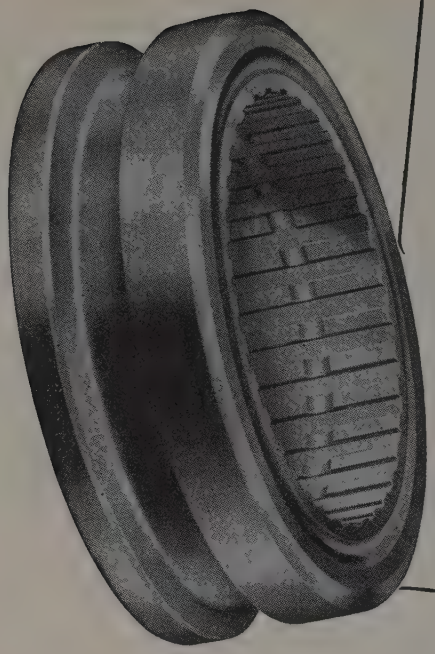
WHEN IT'S AN Exide YOU START



SAE DESIGNATIONS

MATERIALS AND PARTS	DESIGNATION GIVEN IN SAE STANDARD, SAE RECOMMENDED PRACTICE, OR SAE GENERAL INFORMATION REPORT	PAGE	DESIGNATION (*X* STANDS FOR THE VARIOUS DIGITS)
BATTERIES	Storage Batteries	663 663 663 663 663 663 663 663 663 663 663 663 663 663 663 663 663	1H 3H 7G 1M 4D 8D 2H 4G 8G 2M 4H 2E 6D 2F 6G 2L 7D
FLYWHEEL HOUSINGS	Engine Flywheel Housings EngineMountings	722 721, 722 721, 722	SAE 00 SAE 0 SAE 1–SAE 6
ENGINE-ARM DIMENSIONS	Engine Mountings	721 721 721 721 721	1 3 4 5 2T
V-BELTS AND PULLEYS	V-Belts and Pulleys	735 735 735 735 735	$\frac{5}{8}$ $\frac{7}{8}$ $1\frac{1}{16}$ 1 $\frac{3}{4}$
MARINE PROPELLER-SHAFT COUPLING FLANGES	Marine Propeller-Shaft Couplings	801 802 803 801 802 803 801 802 803 801 802 803	1 1S 400 2 2S 500 3 3S 600 4 4S 725



COST WHEN MADE FROM FORGINGS—$1.714	COST WHEN MADE FROM TIMKEN TUBING—$1.47
Cost of forging per unit. $0.4228	Cost of tubing per unit. $0.293
Production cost per unit (broached and then machined on chucking automatic). $1.2912	Production cost per unit (with mill-length tubing on 4-spindle 5″ capacity automatic screw machine) . .$1.177
TOTAL COST PER UNIT— $1.714	TOTAL COST PER UNIT— $1.47

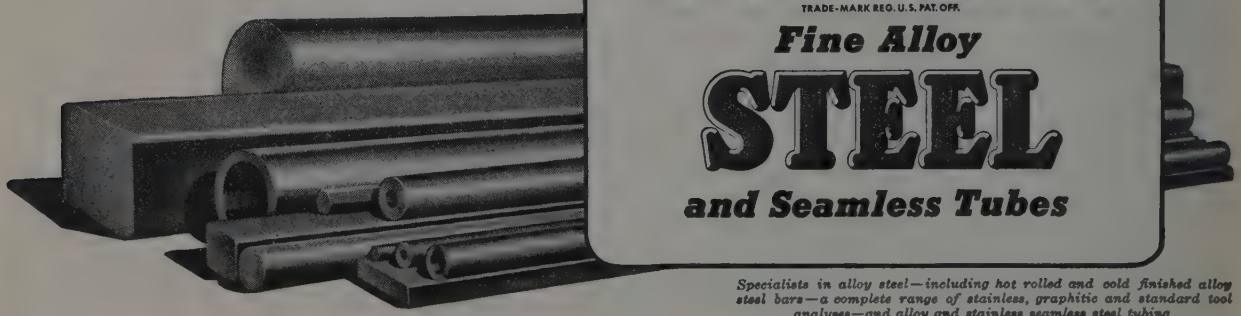
Why this sleeve costs only $1.47 instead of $1.71

WHEN made from forgings, this part cost $1.71 per piece. By switching to Timken® seamless tubing, the manufacturer was able to cut his cost down to $1.47 per piece. Here's why this saving was possible: 1. Unit for unit, Timken seamless tubing was far less expensive than forgings. 2. The mill lengths of tubing could be broached and machined on an automatic screw machine, whereas the forgings had to be broached and then machined on a chucking automatic. Actual cost figures are shown above.

Timken tubing also offers cost advantages over bar stock, as well as forgings. With tubing you can often start right in with finish boring. The center hole is already there. Metal is conserved. Scrap loss is reduced —machining time saved.

And you get better quality too. Timken tubing gives you fine forged quality that's always uniform from tube to tube and heat to heat. For help in choosing the most economical tube size for your job, use our Tube Engineering Service. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO."

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH



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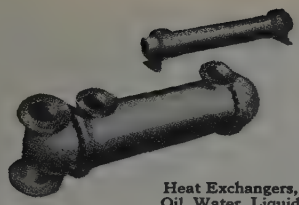
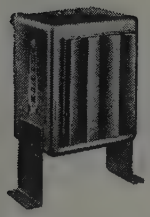


Heat Exchangers, Oil, Water, Liquid and Gas Coolers

Cast Tank Radiators



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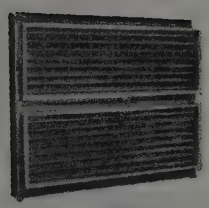
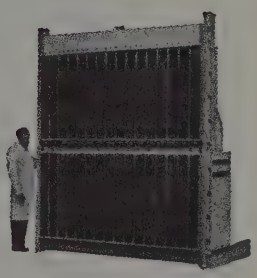
From small car heater cores that can be held in the hand to the huge VAD Vertical Air Discharge coolers and condensers that dwarf a man, Young Engineers have developed a complete line of products capable of handling any heat transfer requirement. Such versatility makes available a single source for your heat transfer needs... assures products that are engineered to work perfectly together. Catalog 148, available upon request, illustrates the broad range of the Young line.

Stamped Tank Sheet Metal Radiators



Locomotive Radiators Complete with Automatic Shutters



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Young Quality

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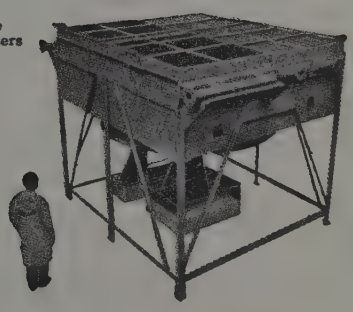
Vertical Discharge Coolers and Condensers



YOUNG RADIATOR COMPANY

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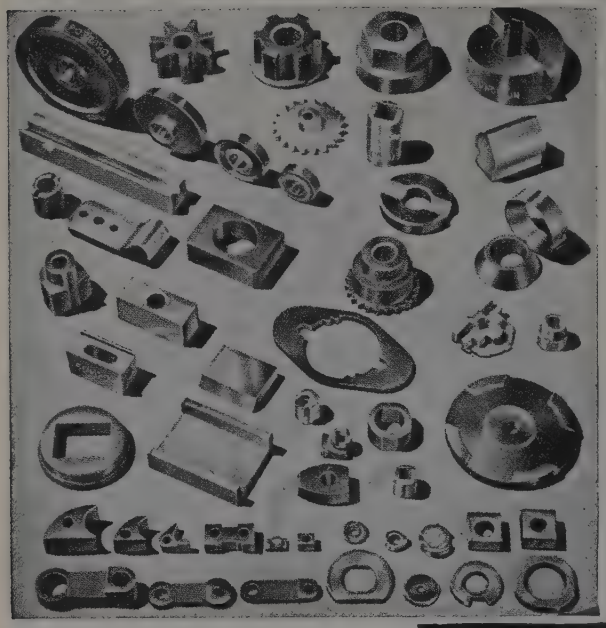

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Organizations Referred to in SAE Handbook

ACI

Alloy Castings Institute
2 Third Avenue
Mineola, L. I., N. Y.
(E. A. Schoefer, Exec. Secy.)

AES

American Electroplaters' Society
P. O. Box 168
Jenkintown, Pa.
(A. Kenneth Graham, Secy.)

AFA

American Foundrymen's Association
222 West Adams Street
Chicago 6, Ill.
(W. W. Maloney, Secy.)

AGMA

American Gear Manufacturers' Association
Empire Building
Pittsburgh 22, Pa.
(Newbold C. Goin, Exec. Secy.)

AISI

American Iron and Steel Institute
350 Fifth Avenue
New York 1, N. Y.
(Walter S. Tower, Pres.)

API

American Petroleum Institute
50 West 50th Street
New York 20, N. Y.
(W. R. Boyd, Pres.)

ASM

American Society for Metals
7301 Euclid Avenue
Cleveland 3, Ohio
(W. H. Eisenman, Secy.)

ASTM

American Society for Testing Materials
1916 Race Street
Philadelphia 3, Pa.
(C. L. Warwick, Exec. Secy.)

ASAE

American Society of Agricultural Engineers
Box 229
St. Joseph, Mich.
(Raymond Olney, Secy.)

ASME

American Society of Mechanical Engineers
29 West 39th Street
New York 18, N. Y.
(C. E. Davies, Secy.)

ASSE

American Society of Safety Engineers
20 North Wacker Drive
Chicago 6, Ill.
(Albert Caddell, Secy.)

ASA

American Standards Association
70 East 45th Street
New York 17, N. Y.
(George F. Hussey, Secy.)

ATA

American Trucking Associations
1424 16th Street
Washington 6, D. C.
(John V. Lawrence, Managing Dir.)

AWS

American Welding Society
29 West 39th Street
New York 18, N. Y.
(Harry E. Jordan, Secy.)

AFBMA

Anti-Friction Bearing Manufacturers Association
60 East 42nd Street
New York 17, N. Y.
(H. O. Smith, Secy.)

ALAM

Association of Licensed Automobile Manufacturers
(defunct)

AMA

Automobile Manufacturers Association
New Center Building
Detroit 2, Mich.
(William J. Cronin, Managing Dir.)

CRC

Coordinating Research Council
30 Rockefeller Plaza
New York 20, N. Y.
(M. K. McLeod, Mgr.)

(*Continued*)

Anaconda Copper & Copper Alloys

THE AMERICAN BRASS COMPANY produces copper and copper alloyed with zinc, tin, nickel, lead, aluminum, manganese, silicon, cadmium, chromium, selenium and other elements in all combinations that can be wrought into commercial shapes. Several of the more important engineering alloys are as follows:

EVERDUR* This group of high-strength, corrosion-resistant alloys is composed basically of copper, silicon and other elements. They were developed for structural and engineering uses which require metal with high tensile strength and good fabricating properties combined with an immunity to rust and corrosion resistance equivalent to copper. Everdur is available in practically all commercial shapes, welding rods and special products.

PHOSPHOR BRONZE This term is assigned to copper-tin alloys in which the oxides have been eliminated by the addition of phosphorus. The component parts, when correctly adjusted, produce fine-grain, homogeneous metal, possessing high tensile strength, high elastic limit, high resistance to fatigue, high resistance to corrosion, low coefficient of friction and high resistance to wear. Anaconda Phosphor Bronze Alloys containing from 4% to 10.5% tin have unusually good spring properties and are available in a wide range of tempers.

COPPER-NICKEL ALLOYS The American Brass Company produces Nickel Silver in a wide range of alloys containing copper, nickel and zinc in various proportions, with nickel content ranging from 5% to 30%. Several of the alloys have small quantities of lead added to improve their machining qualities. Cupro Nickel Alloys, composed of copper and nickel, are highly ductile, malleable and corrosion-resistant and are produced with a nickel content of 2.5% to 30%. Ambrac* Metal is a copper-nickel alloy with a small percentage of zinc, originated and sold exclusively by The American Brass Company.

AMBRALOY is a trade name used to designate copper-aluminum alloys manufactured by The American Brass Company. General characteristics of these alloys are good corrosion resistance, high strength, resistance to oxidation at elevated temperatures, and 5% to 10% less weight than other common brass and bronze alloys.

In this group is an alloy specifically developed for use in aircraft engines and sold under the registered trade name, Avialite*. It is furnished in the form of rods for machining and also as die pressed forgings. When so specified on the order, it is manufactured to meet the requirements of S. A. E. Specification 701, Grade B. Specific automotive uses are for valve seats and guides, spark plug inserts, various bushings, nuts, gears and other fabricated parts.

CHROMIUM COPPER 999 is an Anaconda Alloy which can be improved in physical properties and conductivity by heat treatment. The composition of this metal is copper 99.05%, chromium 0.85%, silicon 0.10%. Chromium Copper has high electrical conductivity, which it retains to a remarkable degree at elevated temperatures. It is furnished in the form of strips, rods, bars and wire.

*Reg. U. S. Pat. Off.

Compositions, forms available, physical properties and constants for Standard Anaconda Metals are given in Publication B-32. Specification references are in Publication B-34. Copies will be mailed on request.

ANACONDA from mine to consumer

THE AMERICAN BRASS COMPANY

General Offices: WATERBURY 20, CONNECTICUT

ORGANIZATIONS REFERRED TO IN SAE HANDBOOK

CABRA

Copper and Brass Research Association
420 Lexington Avenue
New York 17, N. Y.
(T. E. Veltfort, Mgr.)

Federal Specifications Board
Room 6008, Federal Supply Services
7th and D Streets, S.W.
Washington 25, D. C.

Felt Association, Inc.
74 Trinity Place
New York 6, N. Y.
(Herbert S. Blake, Secy.)

IES

Illuminating Engineering Society
51 Madison Avenue
New York 10, N. Y.
(A. Dexter Hinckley, Exec. Secy.)

ICC

Interstate Commerce Commission
I. C. C. Building
12th & Constitution Avenue, N. W.
Washington 25, D. C.

NASC

National Aircraft Standards Committee
610 Shoreham Building
Washington 5, D. C.

NACE

National Association of Corrosion Engineers
Southern Standard Building
Houston 2, Texas
(A. B. Campbell, Exec. Secy.)

NBS

National Bureau of Standards
U. S. Department of Commerce
Washington 25, D. C.

National Committee on Uniform Traffic Laws and Ordinances
National Safety Council
425 North Michigan Avenue
Chicago 11, Ill.
(Ned H. Dearborn, Pres.)

NFPA

National Fire Protection Association
60 Batterymarch Street
Boston 10, Mass.
(Percy Bugbee, Gen. Mgr.)

NMTBA

National Machine Tool Builders' Association
10525 Carnegie Avenue
Cleveland 6, Ohio
(Tell Berna, General Mgr.)

OBMA

Outboard Boat Manufacturers Association
307 North Michigan Avenue
Chicago 1, Ill.
(Arnon N. Benson, Exec. Dir.)

OBCA

Outboard Boating Club of America
307 North Michigan Avenue
Chicago 1, Ill.
(Arnon N. Benson, Exec. Dir.)

OMMA

Outboard Motor Manufacturers Association
307 North Michigan Avenue
Chicago 1, Ill.
(Arnon N. Benson, Exec. Dir.)

RMA

Radio Manufacturers Association
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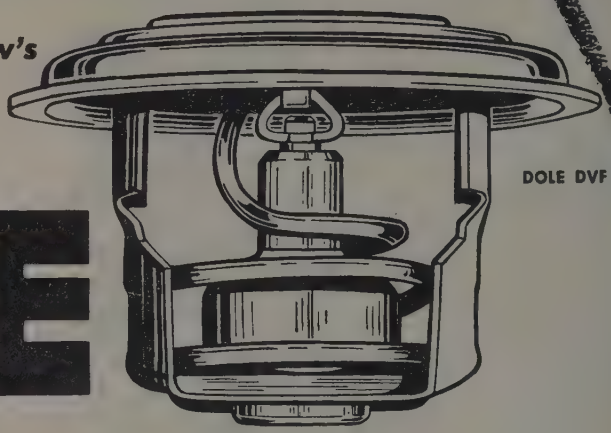

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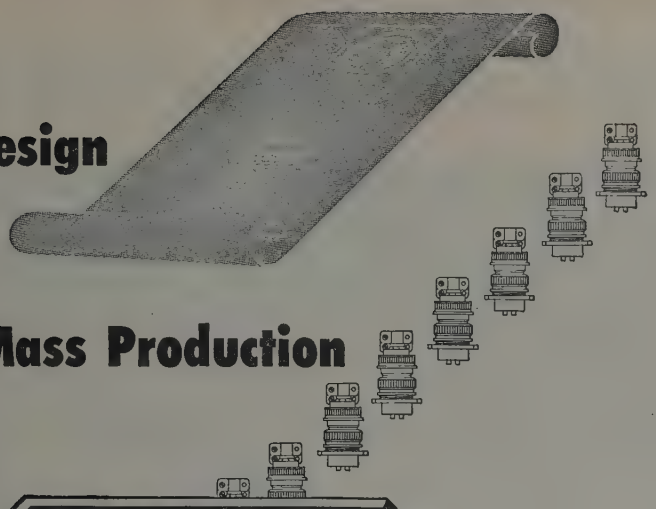

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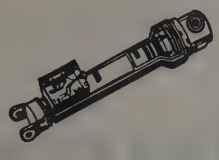

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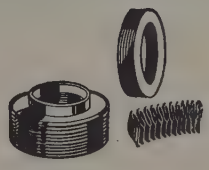

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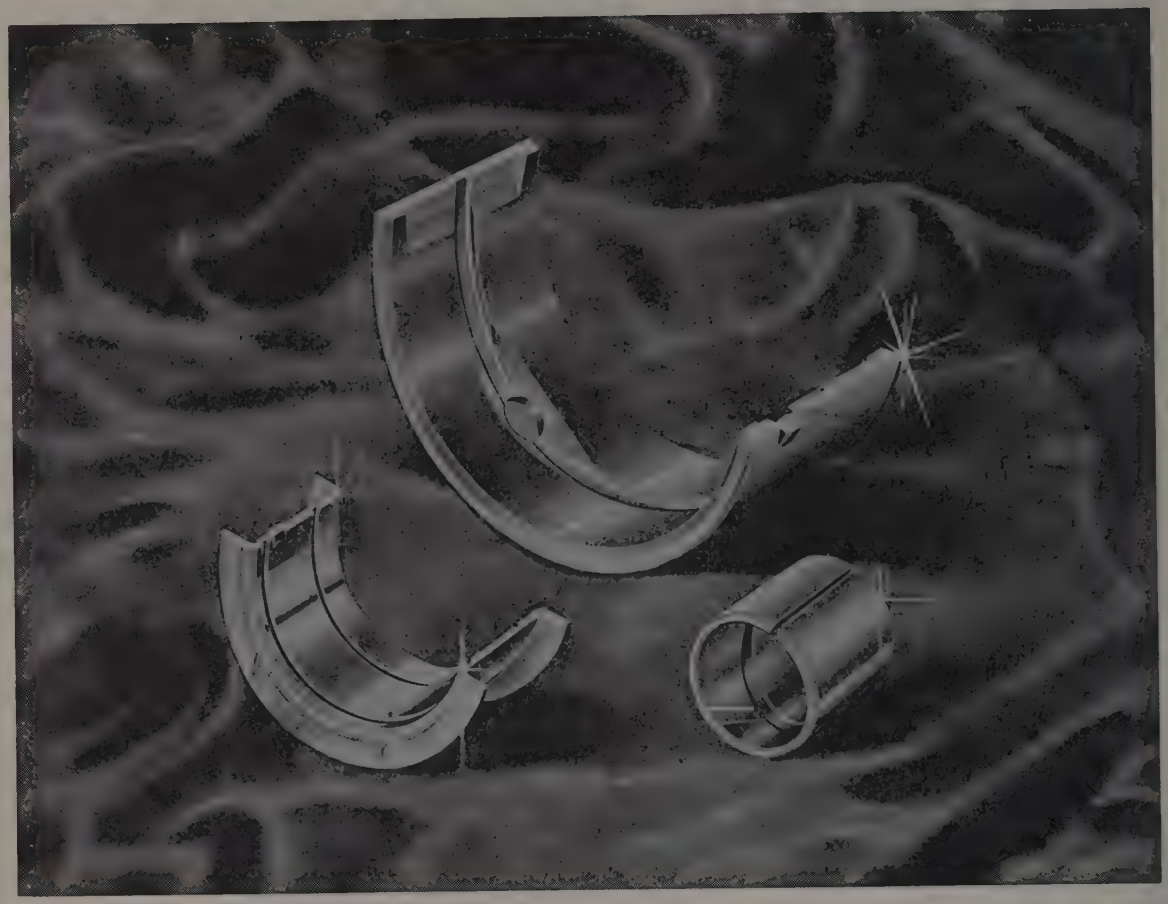

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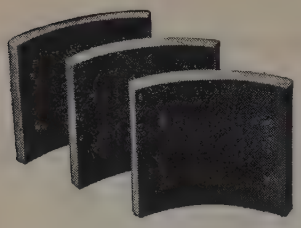

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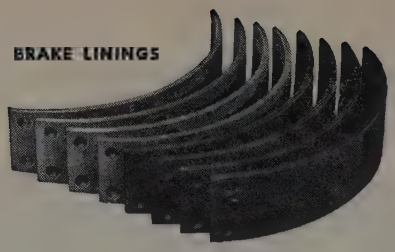

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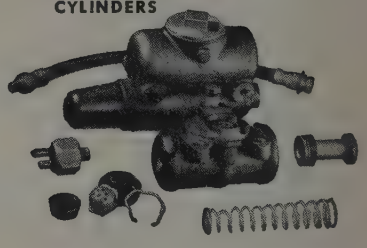

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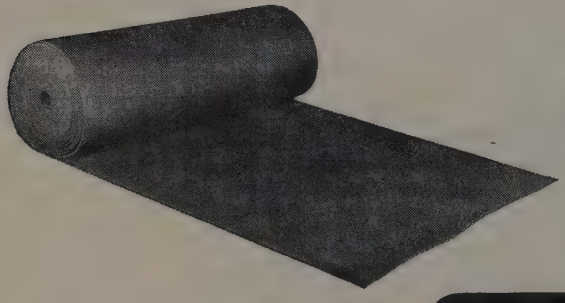

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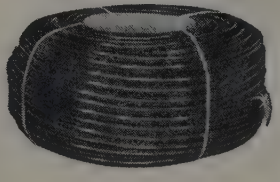

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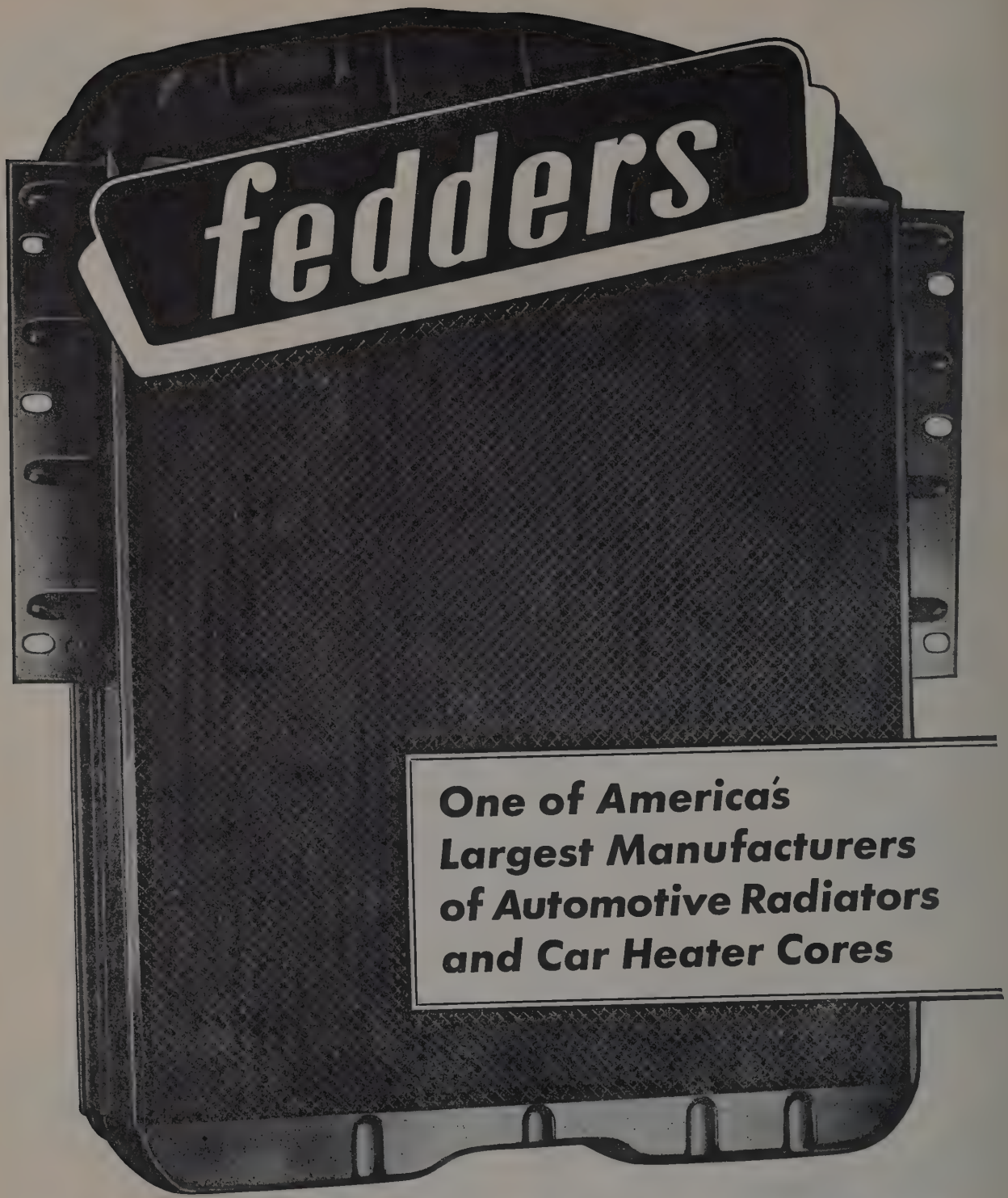

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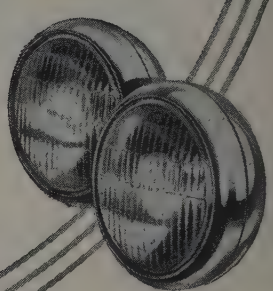

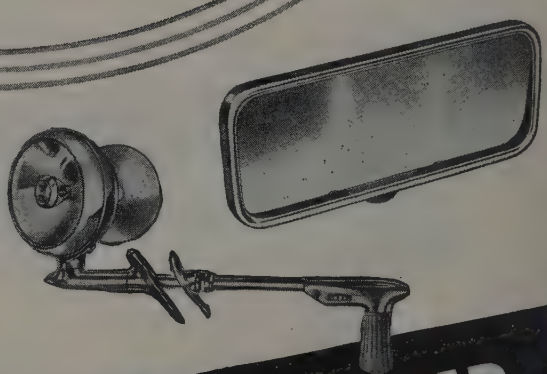

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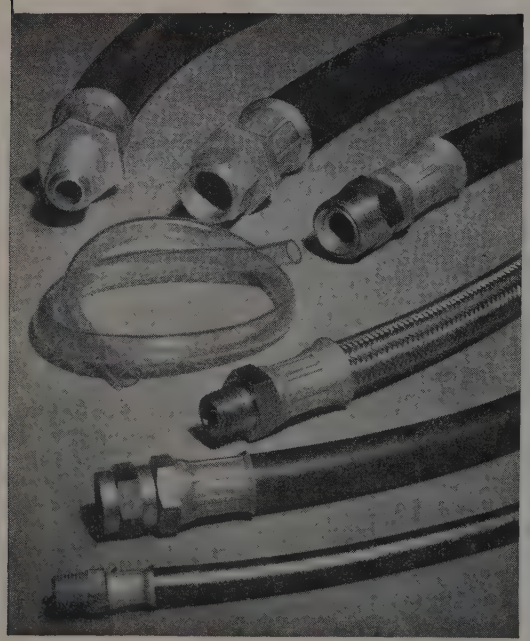

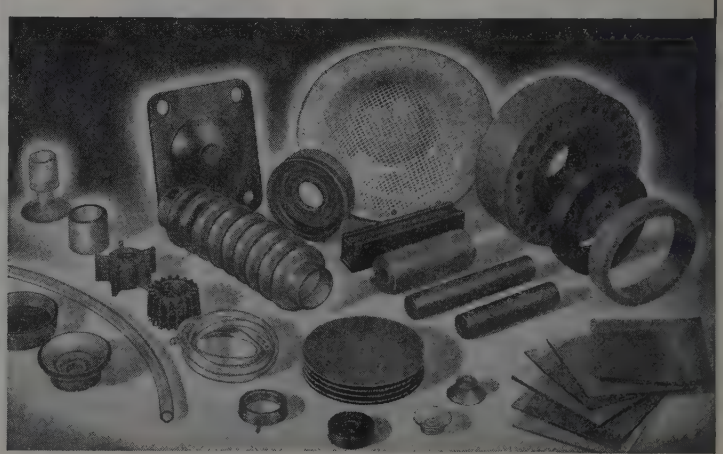

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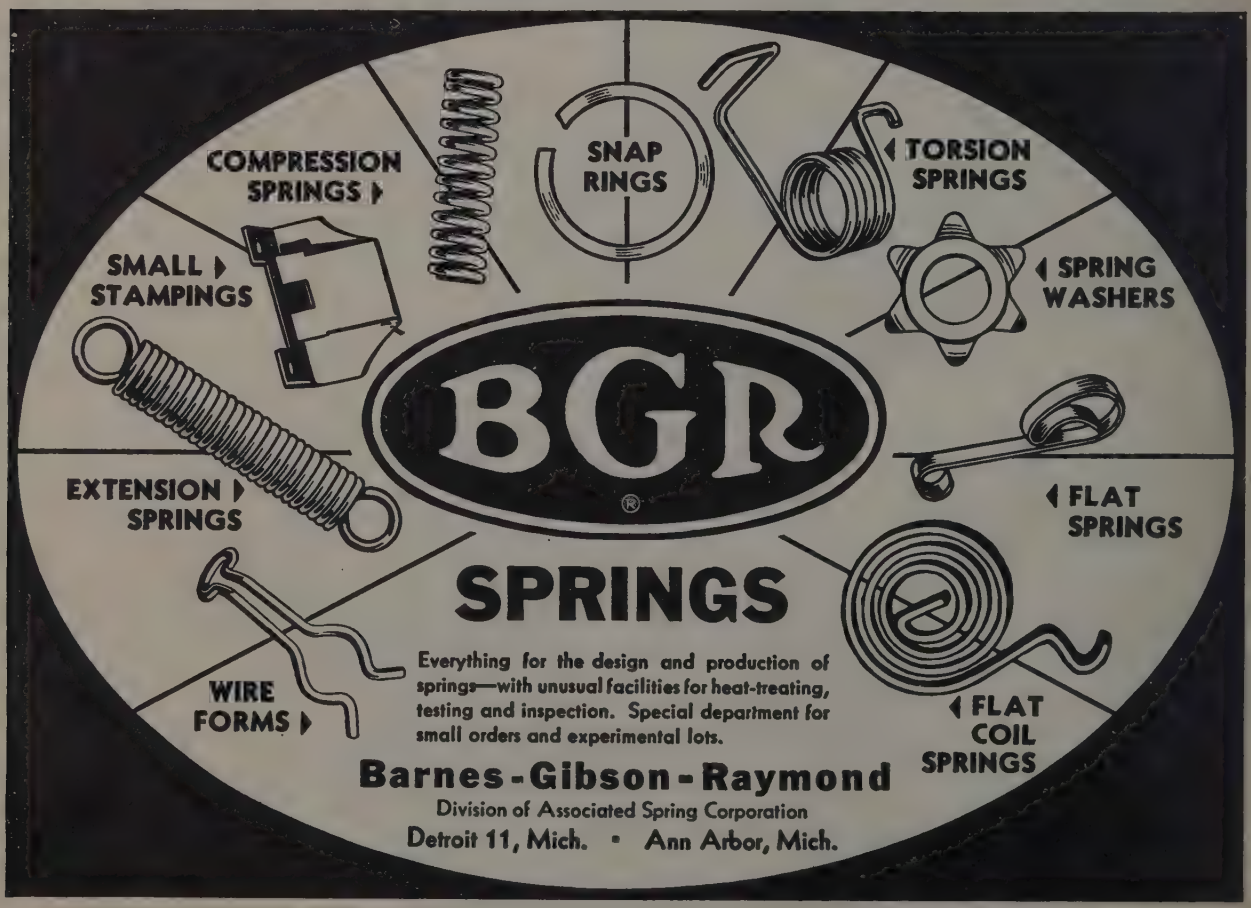

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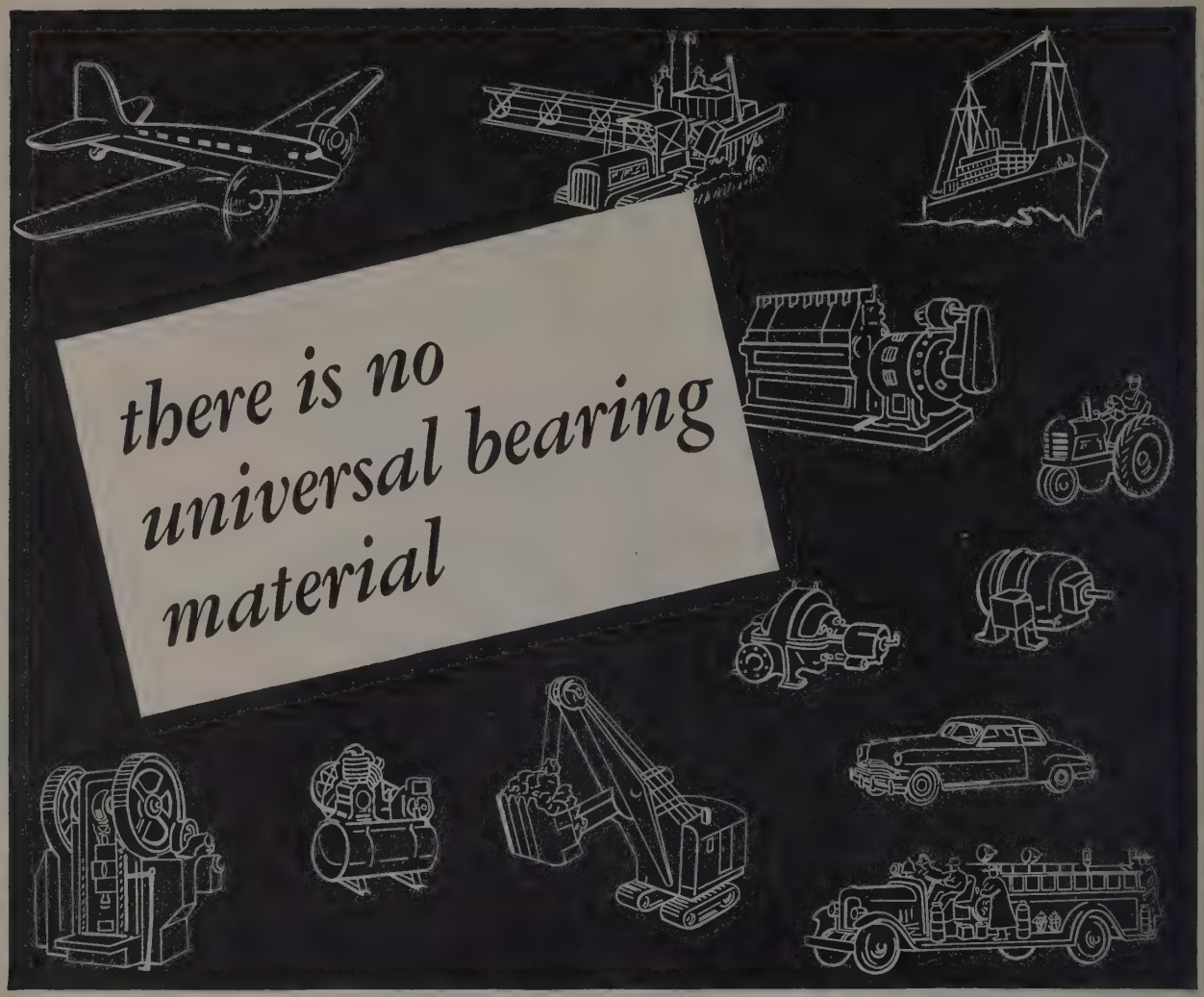

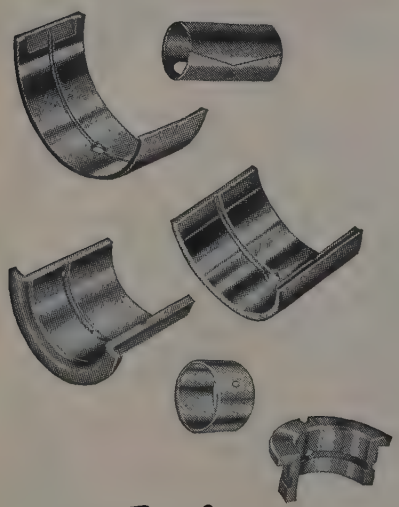

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Warehouse stocks and dealer stocks of Schrader Products in hardware style package units are maintained throughout the world. And wherever there's a Schrader dealer—there too, you'll find tire maintenance know-how.

That's why tire manufacturers have looked to Schrader for their standard valves and air service accessories since the advent of pneumatic tires. Our engineers have a wealth of technical experience that is yours to use. When you think of air—call on us.

A. SCHRADER'S SON, *Division of Scovill Manufacturing Company, Incorporated,* **BROOKLYN 17, N. Y.**

Schrader
REG. U. S. PAT. OFF.

FIRST NAME IN TIRE VALVES
FOR ORIGINAL EQUIPMENT AND REPLACEMENT

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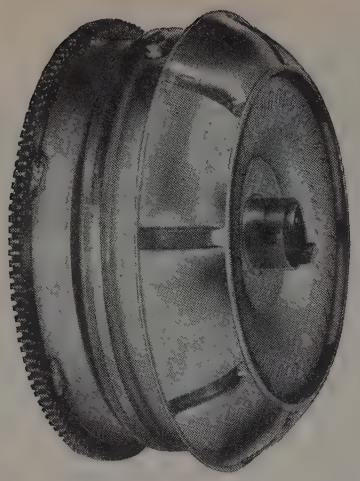
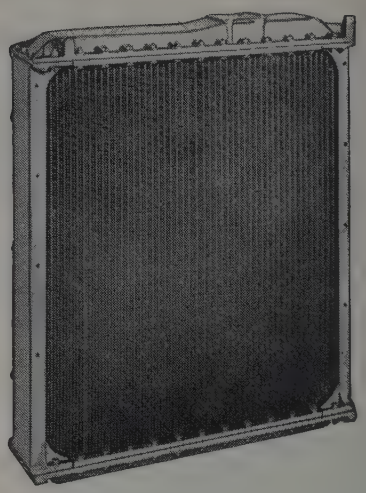


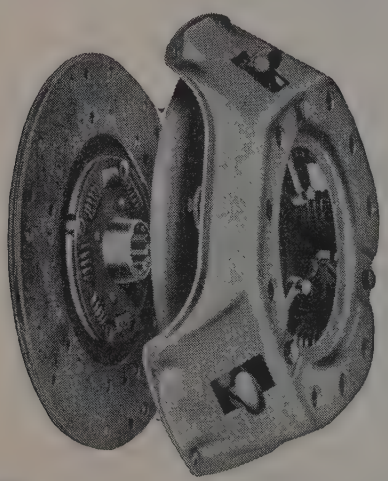
LONG TORQUE CONVERTER

Here's velvet-smooth power transfer, with torque multiplication of better than 2 to 1 at stall. Air-cooled for trouble-free service. Assembly units fabricated almost entirely from stampings for low-cost production.

LONG RADIATORS

Long radiators and maximum heat exchange have been synonymous throughout the automotive world since 1903. Fin-and-tube design and construction provide clean, unobstructed water courses. Capacities range from passenger car models to heaviest-duty commercial vehicle types.





LONG CLUTCHES

Effortless operation, dependable performance in stop-and-go traffic driving. At highway speeds, semi-centrifugal design gives increased torque capacity . . . less slippage, less wear. Long clutches have equipped millions of cars, trucks, buses and tractors since 1922.

ENGINEERING B-W PRODUCTION

LONG MANUFACTURING DIVISION
BORG-WARNER CORPORATION
DETROIT 12 and WINDSOR, ONTARIO

LONG

TORQUE CONVERTERS • CLUTCHES • RADIATORS • OIL COOLERS

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What sales appeal never changes?.

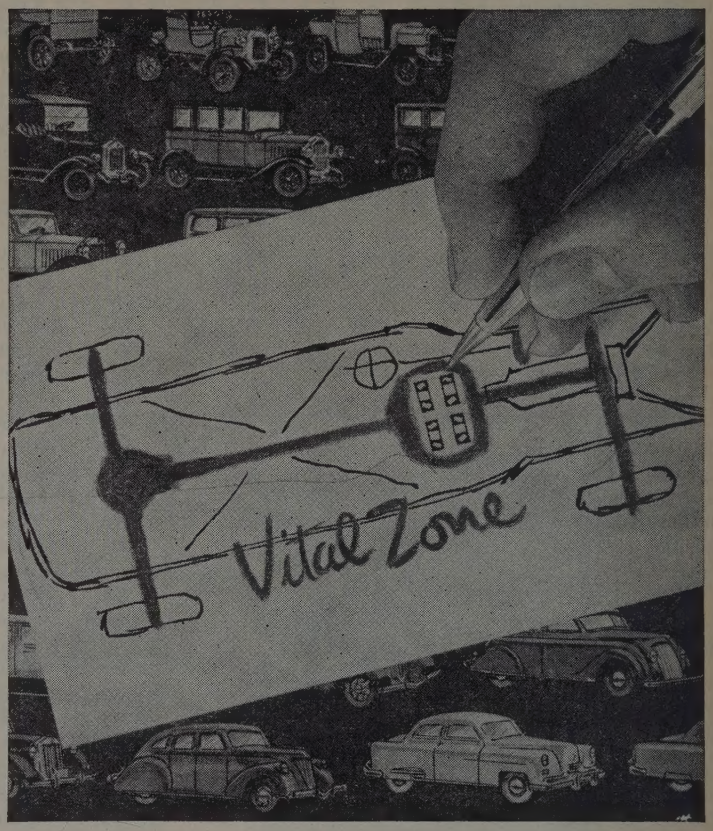
PROGRESS moves fast in the automotive industry. Each year has seen a new array of exciting sales features.

Back in 1905, a power tire pump captured many a customer's fancy. In 1907, nickel-plated trim became the rage. Adjustable front seats set car buyers agog in 1926. Lately it's been automatic transmissions of various types. The emphasis has shifted from one sales feature to another. But through it all there has run one *basic* sales appeal—and that's value. Today, customers are becoming more conscious of value than ever. Especially where it counts the most —in moving parts—the "vital zone".

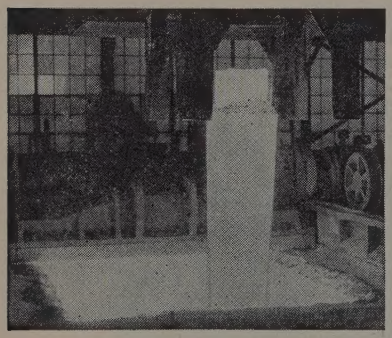
In buying parts for the "vital zone", this simple guide to value may be helpful:

$$Value = \frac{quality + service + public\ acceptance}{price}$$

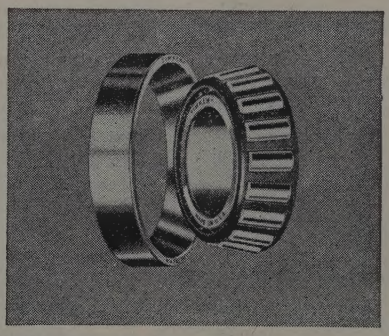
It shows that price is only *one* factor in value, and must be weighed in relation to the factors *above* the line. Timken® bearings give you far more above the line than any other tapered roller bearing (see chart at right below). And in terms of value features, Timken bearing prices are lowest today. So by this formula or any other, your best value in tapered roller bearings is Timken! The Timken Roller Bearing Company, Canton 6, Ohio.



How TIMKEN® bearings give you value where it counts most . . . in the "vital zone":



WE MAKE OUR OWN STEEL—because it is the only way we can get the consistently high quality steel required for Timken bearings. And because it gives us quality control from start to finish. The Timken Company is the only bearing manufacturer in America that makes its own steel.



FIRST CHOICE FOR PINIONS! All but two makes of cars use Timken tapered roller bearings on the pinion, toughest bearing application in the car. And in many other places in the vital zone such as wheels, transmissions, differential, etc., Timken bearings give value where value counts.

ONLY TIMKEN BEARINGS GIVE YOU ALL THESE VALUE FEATURES

QUALITY

1. Design leadership
2. Steel made in our own mill
3. Precision manufacture
4. Rigid quality control
5. 50 years experience

SERVICE

6. Unequalled engineering service
7. Unequalled research and development facilities for your use
8. Installation service in the field
9. Widest range of sizes
10. Most dependable source of supply

PUBLIC ACCEPTANCE

11. First choice throughout industry
12. Best-known name in bearings
13. Widespread advertising

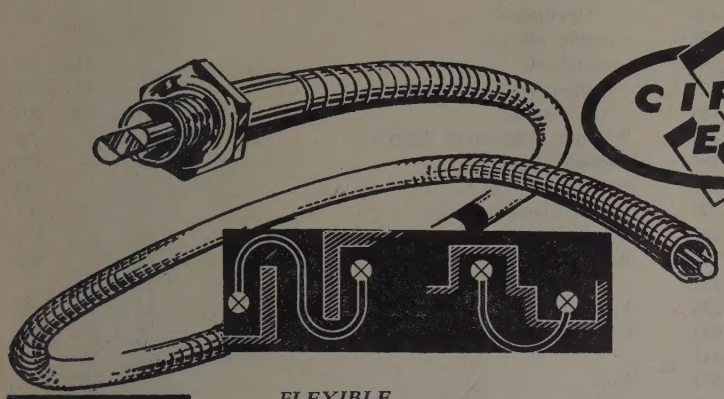
it's TIMKEN for VALUE

TRADE-MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS

NOT JUST A BALL ◯ NOT JUST A ROLLER ⬭ THE TIMKEN TAPERED ROLLER ⬭ BEARING TAKES RADIAL ⓪ AND THRUST →⓪← LOADS OR ANY COMBINATION

REDUCE YOUR NUMBER OF PARTS
and Permit a Logical Grouping of Working Units



Flexible
SHAFT ASSEMBLIES

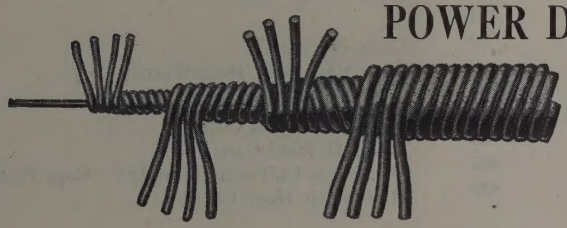
Due to our wide experience in developing flexible shafts for carrying power around any corner, we can give you immediate help in solving your alignment problem. Circle Ess Flexible Shafts are today serving in the machinery, electronics, automotive, and aircraft industries where, in numerous cases, many new problems were solved.

FLEXIBLE SHAFTING MADE IN STANDARD SIZES OR TO YOUR SPECIFICATIONS

It is not necessary for you to use expensive arrangements of mitre gears, universal joints, spur gears, and other space wasting constructions. The answer to simplified arrangement, inexpensive, efficient performance, is in the transmittal of power around bends with Circle Ess Flexible Shafts.

Mechanical and electrical controls may be placed in a position for economical yet highly efficient construction and still be operated from a readily accessible point through use of a flexible shaft assembly.

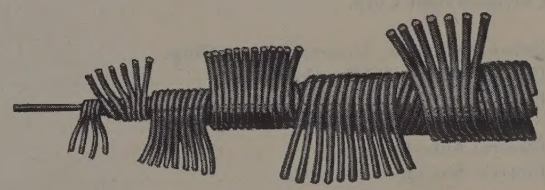
POWER DRIVE SHAFT



This shaft is used in transferring power around corners and under or over necessary obstacles. It has many advantages over the solid shaft—it eliminates mitre gears, bevel gears, universal joints, and the costly production time that is spent in aligning solid shafts. Pictured is a section of Power Drive Flexible Shafting showing construction of superimposed layers of wire wound in opposite directions.

REMOTE CONTROL SHAFTS

This type is used when a driven element needs to be moved only a fraction of a turn or several complete turns. Also used when it is necessary to both rotate and reciprocate, such as the opening and closing of valves. The designer is free to place the controls of a product in a position that is centrally located and accessible. Picture shows construction of superimposed layers of wire wound in opposite directions.



OUR ENGINEERING DEPARTMENT *is at Your Service*

We wish to extend to every plant executive and plant engineer, the facilities of our engineering department so that they may have the full use and benefit of the vast amount of practical Circle Ess data which has been compiled over many years. Our engineers, with specialized experience, are ready to help you in selecting the proper material for your needs and should it be necessary, our complete laboratory facilities are available to test your equipment to obtain design data.

Write for our book "FLEXIBLE SHAFT ASSEMBLIES"

It has valuable information for all automobile and other manufacturers where power drives or remote controls are required.

CIRCLE ESS

F. W. STEWART MFG. CORPORATION

4311-13 RAVENSWOOD AVE. CHICAGO 13, ILL.

WEST COAST BRANCH: 431 VENICE BLVD., LOS ANGELES 15, CAL.

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